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Effects of harvest date, harvest time, and post-harvest management on quantitative and qualitative traits in seedless barberry (*Berberis vulgaris* L.)

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ABSTRACT

Seedless barberry is a native medicinal shrub that has been cultivated in Iran for more than two centuries. In order to study the effects of harvest dates, harvest times-of-day, drying and harvest methods on quantity and quality of seedless barberry fruits, three separate experiments were conducted in Soorand, Southern Khorasan province, Iran in 2008 and 2010. In the first experiment the effects of different harvest dates (9 September, 1 October, 22 October and 13 November), in the second experiment five harvest times-of-day (07.00, 10.00, 13.00, 16.00 and 19.00 O'clock) at two dates of harvest (16 September and 17 October) and finally in the third study the effect of picking methods (branch cutting and berry picking) and drying methods (sun drying and shade drying) were studied on quantitative and qualitative indices of seedless barberry. Results showed that the highest fresh and dry fruit yields were obtained at the final harvest date (13 November) in the first experiment. Moreover, the brix, pH and anthocyanin fruit content were increased but total titratable acidity was decreased by delaying in harvest date. Qualitative indices of seedless barberry were in maximum values before sunrise, then were decreased until noon and after that were increased until sunset. The maximum and minimum brix values were obtained at 07.00 and 10.00 (12.7% and 9.7%, respectively). In addition, the highest maturity index and anthocyanin fruit content (mg/100 g dry berries) were obtained at 7.00 (3.40 and 128.5, respectively) and the lowest values of these indices were observed at 10.00 (3.03 and 83, respectively). The maximum value of brix (9.8%), total titratable acidity (3.5%), maturity index (2.8) and anthocyanin fruit content (63.5 mg/100 g dry berries) were observed in berry picking method. Moreover, the highest brix value (9.8%), total titratable acidity (3.6%), maturity index (2.7) and anthocyanin fruit content (72.5 mg/100 g dry berries) were obtained in the sun drying method. Generally, results of these experiments showed that berry picking in cool hours during the day and sun drying method are effective ways for improving barberry qualitative indices.

1. Introduction

Recently, much attention has been done on small fruits such as barberry (*Berberis vulgaris* L.) that are considered as a source of medicinal compounds (Arena and Curvetto, 2008). Barberry is a dicotyledon, perennial species and well-known medicinal shrub in Iran (Shamsa et al., 1999; Rezvani Moghaddam et al., 2007; Ebadi et al., 2010). It is cultivated as a domestic plant in Southern Khorasan province in eastern part of Iran since 200 years ago (Kafi and Balandari, 2004; Rezvani Moghaddam et al., 2007; Aghbashlo et al., 2008; Fallahi et al., 2010). Currently, barberry is cultivated in more than 11,000 hectares with annual production about 9200 tons dry fruit in this region (Radmehr, 2010).

Seedless barberry is one of the economical sources of anthocyanin pigments (Fallahi et al., 2010). Recently, there has been a great increase in utilization of anthocyanin in the food industries, replacing artificial coloring agents (Laleh et al., 2006; Fan et al., 2008). Many studies showed that qualitative indices of berries such as anthocyanins and soluble solids are affected by many environmental factors such as temperature and light intensity (Bergqvist et al., 2001; Budic-Leto et al., 2006; Yamane et al., 2006; Laleh et al., 2006; Tiwari et al., 2009). In addition, it is well documented that quantity and quality of barberry fruits are affected by harvest date and drying and harvest methods (Chandra and Todaria, 1983;

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Balandari, 1992; Arena and Curvetto, 2008; Fallahi et al., 2010; Rezvani Moghaddam et al., 2011).

Chandra and Todaria (1983) in a study on three barberries species were concluded that, soluble sugar and anthocyanin content were increased simultaneously with fruit maturation and ripening. Also, Bonerz et al. (2007) reported that anthocyanins are not stable during storage and processing stage. Results of Balandari (1992) showed that soluble solid and maturity index of seedless barberry were increased by delaying in harvest date and reached to the maximum values on 10 November. Arena and Curvetto (2008) in a similar work on *Berberis buxifolia* have been reported that fruit quality significantly changed during the fruiting period and different growing seasons. Their results revealed that the maximum fruit biomass was obtained 112 days after full flowering while, the highest soluble solids and anthocyanin contents and the lowest value of total titratable acidity were obtained by day 126 from full flowering. Results of Fallahi et al. (2010) on *B. vulgaris* showed that the best harvest date was in mid-November that improved its fruit quality and yield. In addition, Rezvani Moghaddam et al. (2011) in studies on seedless barberry were reported that fruit quality was influenced by the harvest and drying methods. They emphasized that berry picking and sun drying methods are suitable for fruit quality improving.

Because of limited cultivation of seedless barberry to a small area around the world, there are a few studies conducted on this medicinal shrub. Therefore, the aims of this study were determining the effects of early and late harvest dates on quality and quantity of fruit, evaluation the effects of harvest times-of-day on qualitative indices, and assessment the best harvest and drying methods for seedless barberry.

2. Materials and methods

2.1. Monthly harvest date

In order to study the effects of different harvest dates (10 September, 2 October, 23 October and 13 November) on quantitative and qualitative indices of seedless barberry, an experiment was conducted in a Complete Randomized Block Design with three replications in Soorand, Southern Khorasan province, Iran, in 2008 and 2010. Each treatment contained 15 shrubs (five shrubs per replicate). In each harvest date, berry length, 100 berry fresh weights, 100 berry dry weights, fresh and dry fruit yields were measured.

Measurement of qualitative indices of dried berries was done in laboratories of Food Sciences Department, Ferdowsi University of Mashhad, Iran. For aqueous extracting 20 g milled dry berries were soaked in 50 ml distillated water and then were filtered and the volume reached to 100 ml. The soluble solid (°Brix) and pH of aqueous extract were determined by refractometer and pH meter, respectively (Bideli, 2000). For measuring total titratable acidity, 5 ml from prepared extract was reached to volume of 100 ml by distillated water, then titration of diluted extract was done by 0.1 N NaOH till reaching to end of operation (pH = 8.23). Finally, total titratable acidity was calculated based on malic acid, using Eq. (1) (Bideli, 2000).

$$\text{Acidity} = \left(\frac{V \times N \times M}{2000}\right) \times A \quad (1)$$

where V is the used volume of NaOH (ml), N the NaOH normality, M the molecular weight of malic acid and A is the dilution factor.

In addition, the anthocyanin content (mg/100 g dry berries) was determined by using the Timberlake and Bridle (1982) method.

Table 1
Temperatures recorded at different times of harvesting at 16 September and 16 October, 2010.

	07.00	10.00	13.00	16.00	19.00
16 September	13 °C	21 °C	32 °C	19 °C	15 °C
16 October	4 °C	17 °C	27 °C	15 °C	11 °C

2.2. Harvest times-of-day

This experiment was conducted as a split plot in time based on Complete Randomized Block Design with three replications in Soorand, Southern Khorasan province, Iran, in 2010 year. Each replicate contained five barberry shrubs. The experimental treatments were five different harvest times-of-day on 16 September and 16 October, 2010. Harvesting was done every three hours which started from 07.00 (before sunrise) and ended at 19.00 (after sunset). Different hour's temperatures were recorded on 16 September and 16 October (Table 1). The qualitative indices such as pH, brix percentage, total titratable acidity and anthocyanin content were measured in each harvest time.

2.3. Harvest and drying methods

This study was conducted as a factorial experiment based on Complete Randomized Block Design with three replications in Soorand, Southern Khorasan province, Iran, in 2010. Experimental factors included picking methods (branch cutting and berry picking) and drying methods (sun drying and shade drying). The indices such as pH, soluble solids (Brix) and total titratable acidity were determined in berry samples; also the amount of anthocyanin content was measured by Timberlake and Bridle (1982) method. Maturity index (MI) defined as brix to total titratable acidity percentage ratio (Fallahi et al., 2010).

In each of three experiments, data analysis was carried out using SAS 9.1 and means were compared by the Duncan multiple ranges at the 5% level to distinguish the different treatments.

3. Results and discussion

3.1. Harvest date

Results of combined analysis showed that year and harvest date had significant effect on quantitative and qualitative indices of seedless barberry ($p < 0.01$). The lowest and highest berry length, 100 berries fresh and dry weights, fresh and dry fruit yield were obtained at the first and final harvest dates, respectively (Table 2). Moreover, all of the qualitative indices, except total titratable acidity had an increasing trend by delaying in harvest date. The highest pH, brix, maturity index and anthocyanin content of berries were obtained on 13 November and the lowest were observed on 10 September (Table 2). These results were corresponding with results of Chandra and Todaria (1983), Balandari (1992), Arena and Curvetto (2008) and Fallahi et al. (2010). In a study on three *Berberis* species it was reported that soluble solid and anthocyanin content were increased during fruit maturation stage (Chandra and Todaria, 1983). Balandari (1992) and Fallahi et al. (2010) have been concluded that berry weight, fruit yield, pH, soluble solids, maturity index and anthocyanin content of seedless barberry were increased while total titratable acidity was decreased by delaying in harvest date.

At the final harvest date the soluble solids content was increased. These components are produced from hydrolyzing sucrose to glucose and fructose during fruit dehydration (Arena and Curvetto, 2008). Considering increasing fresh fruit weight in the experimental period, it seems that hydrolyzing sucrose has been