Effects of preconditioning on quality of dried blueberries

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Abstract

Blueberries are a rich source of phenolic compounds, especially anthocyanins, which contributes to their high level of antioxidant activity. However, these compounds of significant health benefit will be degraded after the blueberries undergo various air drying processes. Drying of blueberries can be difficult due to the wax layer surrounding the fruit. The health properties may be reduced to a large extent due to long exposure to high temperature. In this study, a mechanical wax abrasive pretreatment is used to carefully remove the wax layer and reduce drying time. The abrasive drum was lined with medium grain sand paper and attached to a constant speed rotator. The amount of blueberries and the rotating time were optimized to reduce the damage to the blueberries. Rabbiteye blueberries cv. Climax were used as the test fruit. A laboratory scale cabinet dryer was operated at temperatures between 50 and 90ºC with single stage and multistage drying strategies. The drying rates, colour and level of phenolic compounds and antioxidant activity were evaluated.

Keywords: Blueberries, Air drying, Wax abrasive pretreatment

1. Introduction

It has been reported that consumption of blueberries contributes to a decrease in risk of cardiovascular diseases, inhibition of the growth of cancer cells and prevention of neurodegenerative diseases such as Alzheimer's disease (Heinonen et al., 1998; Seeram, 2008; Singh et al., 2008). The protective effects against diseases have been attributed to various antioxidants contained in blueberries. In addition to well-known vitamin C, phenolic compounds, especially anthocyanins, make a significant contribution to the total antioxidant activity due to their high concentration in blueberries (Prior et al., 1998). However, the antioxidants can be affected by processing conditions after harvest including heat, pH, oxygen and various storage conditions which result in alteration of the biological activity (Kalt et al., 2000).

The issue of seasonal availability may limit the consumption of fresh blueberries. Drying is, therefore, one of the methods employed to extend the availability of blueberries out of season. The drying process involves reduction of water content to the level at which the spoilage by micro-organisms or other reactions that cause deterioration are minimized or eliminated. Drying of blueberries can be difficult because blueberries contain a wax outer skin layer which acts as a barrier to moisture movement across the membrane. Therefore, various drying methods and pretreatments have been investigated and introduced. The food industry generally uses chemical pretreatment or osmotic dehydration to improve the drying rate and other related quality parameters. However, the cost of chemicals can be high. In addition, consumers increasingly prefer fruit that are naturally dried without chemicals. Dipping blueberries in an osmotic solution prior to drying is another alternative. It involves the use of inexpensive sugar to remove large amount of water from the fruits. Nevertheless, even though osmotic solutions can aid moisture loss and solid gain before drying, nutritive components from inside such as acids and phenolic compounds can be leached out during soaking (Raoult-Wack et al., 1992).

Due to these problems, mechanical means of wax removal have gained interest. The idea is derived from the abrasive mechanical skin/peel removal for crops such as potatoes. The raw materials are fed onto an abrasive roller or into a rotating bowl, the surface of which is made of carborundum or protrusions in a stainless steel sheet. The rough surface helps in the removal of the waxy skin coating that is then washed away by water. The benefits of the mechanical pretreatment include low energy cost, low capital cost and no heat damage. The factors which need to be considered include time, load, and drum speed (Singh and Shukla, 1995).

In this study, we aim at investigating the efficiency of wax abrasive pretreatment that will be used with single-stage or mult-stage hot air drying. It is expected that the investigated drying method could have

benefit in lowering the cost of production as well as preserving the quality and nutritional value of the dried blueberries.

2. Materials and methods

2.1. Blueberries

Rabbiteye blueberry (*Vaccinium ashei* Homebell) cv. Climax was obtained from Berry Exchange Farm, Corindi, New South Wales, Australia. The fruits were harvested based on colour at mature stage and stored in a box at ambient temperature for approximately 6 h before reaching the laboratory. The sample was further stored in the freezer at -18ºC until analysis.

Table 1 Level of damage after skin abrasive pre-treatment.

Level	Appearance
1	The berries remained in the same condition as the raw material (unbruised and undamaged). Cuticle was partially removed.
2	The berry's texture was softer than that of the raw material. There was no obvious damage observed on the skin of blueberries (see Figure 2).
3	1-3 damaged berries in a 50 g batch due to excessive skin abrasion. This damage could cause the loss of the pigment during the process (see Figure 3).
4	More than 3 damaged berries. Large amount of pigments and juice from the berries were lost. The berries were very soft.

2.2. Mechanical skin abrasive pre-treatment

A rotating drum was constructed for removing the cuticle of blueberries. The main part of the machine was an abrasive drum made of tin, lined on the inside with medium-grain sand paper. The tin sheet was 13.9 cm in length and 6.5 cm in diameter. The drum was fixed on a horizontal shaft which was attached to a constant-speed rotator. A blueberry sample of approximately 50 g was rotated in the drum for 7 min prior to drying. The drum speed was set at 100 rpm. Under these optimum conditions, the level of damage that was observed was minimised, based on the appearance of blueberries after abrasion..

2.3. Drying procedure

Drying of blueberries was carried out using our laboratory scale cabinet dryer. The dryer was turned on to achieve a steady-state temperature before loading the sample. The selected drying temperature was 70ºC for single-stage drying and for the multistage drying, the temperature profile was 90ºC for 90 min, then 70ºC for 120 min and finally 50ºC until a moisture content of 10-12% was reached which was equivalent to water activity (A_w) of 0.60 - 0.65. At this A_w products are believed to be stable and less likely to be subject to microbial spoilage. Relative humidity was maintained at 10±2% throughout the experiment and the air velocity was 2 m s^{-1}.

2.4 Extraction of anthocyanins and other phenolics

A 10-g sample of dried blueberries was ground in a mortar and then mixed with 75 mL of extracting solvent consisting of methanol:water:acetic acid at a ratio of 25:24:1. The extract was centrifuged at 15ºC, 13,000 rpm for 20 min. After removing the supernatant, the residue was mixed again with 75 mL of the extracting solvent followed by centrifugation. The combined supernatants were evaporated using a rotary evaporator at 35ºC. The residue obtained after evaporation was mixed with 5 mL of 3% (w/v) formic acid in water. Then it was loaded on a C18 Sep-Pak cartridge by using 3% (w/v) formic acid in methanol to elute the anthocyanins and other phenolic compounds. The eluted solution from Sep-Pak was evaporated by the rotary evaporator at 35ºC until a dry residue was obtained. The residue was then dissolved with 3 mL of 3% (w/v) formic acid in 15% methanol and filtered through 0.45 µm Millipore filter for further analysis.

2.5. Determination of total anthocyanins

Total anthocyanins determination was performed using spectroscopic pH-differential methods of Giusti and Wrolstad (2001). Samples were diluted in two buffers which were potassium chloride (pH 1.0) and sodium acetate (pH 4.5), then measured at 520 and 700 nm using UV-1601 Shimadzu UV-visible spectrophotometer (Shimadzu Scientific Instruments, Oceanic Pty. Ltd., NSW, Australia). Total

anthocyanin content was based on cyanidin-3-glucoside with a molar extinction coefficient of 26900 and molecular weight of 449.2. The results were expressed as mg of cyanidin-3-glucoside equivalent per g dried weight (mg C3G eq g^{-1} DW).

2.6. Determination of total phenolics

Total phenolics were determined by colorimetric method using Folin-Ciocalteu reagent (Slinkard and Singleton, 1977). A 150 µL volume of the diluted extract was mixed with 2.4 mL of distilled water and 150 µL of 1:10 diluted Folin-Ciocalteu reagent (2N). The mixture was allowed to react for 2 min before adding 300 µL of Na_2CO_3 solution (7.5% w/v) and mixed well. After 2 h incubation in darkness at room temperature, the absorbance of the solutions was measured at 765 nm. Gallic acid (0-0.1 mg ml^{-1}) was used to establish a standard curve. The results were expressed as mg gallic acid equivalents per g dried weight (mg GAE g^{-1} DW).

2.7. Determination of antioxidant activity

Antioxidant activity was determined using 2,2-diphenyl-1-picrylhydrazyl (DPPH) as a source of free radical. 100 µL of diluted extract was allowed to react with 2,900 µL of 60 µM DPPH solution (in methanol) for 24 h in darkness at ambient temperature. The absorbance was then taken at 515 nm. Trolox (50-500 µM) was used as a standard and the results were expressed as µM Trolox equivalent per g dried weight (µM TE g^{-1} DW).

2.8. Identification of anthocyanins

A water alliance 2690 HPLC was used in anthocyanins identification. The column 2.1 mm x 150 mm Xterra™ MS C_{18} column (Waters Corp., Milford, MA, USA) was used to carry out the separation.

2.9 Measurement of colour

The surface colour of sample was measured by the colorimeter which offers three values of *L* (lightness), *a* (redness or greenness) and *b* (yellowness or blueness). The sample was packed in a transparent Petri dish. The mean of 10 readings was taken.

3. Results

3.1, Effects of pretreatment and drying temperature on drying time

To compare the effect of wax abrasive pretreatment and temperature on the drying rate, single-stage drying was used to establish the drying curve as shown in Figure 1. The drying curve at 90ºC was steeper than at 70ºC which indicated faster drying rate. Besides, the drying curve of wax removal pretreatment sample was steeper than the sample that had not been pretreated for both temperatures. As a result, the drying time of the pretreated sample required to reach a certain moisture level was shorter. The drying time was reduced from 20 h to 6.5 h at 70ºC and from 15 h to 4 hat 90ºC. In multistage drying, the drying of untreated sample was completed after 27 h while the pretreated sample was 7 h.

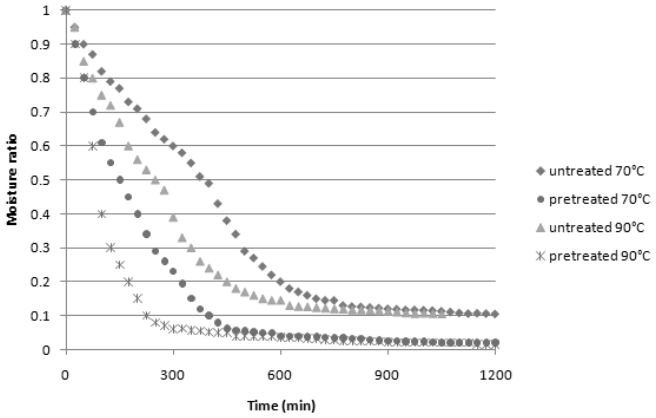

Figure 1 Drying curve of blueberries.

3.2 Determination of total anthocyanins, total phenolics, and antioxidant activity

The results for the effect of each treatment are summarized in Table 2. Fresh blueberries had the highest anthocyanin content, total phenolics, and antioxidant activity which were 14.5, 31.9 and 185.5, respectively. Generally, the wax abrasively pretreated sample showed higher values than the untreated ones. Total anthocyanins in untreated and pretreated samples were highest in drying at 90ºC followed by 70ºC and multistage drying, respectively. The same trend was also observed for total phenolics except between the pretreated sample dried at 70ºC and multistage dried where the values were not significantly different. The antioxidant activity in pretreated samples did not vary significantly between berries dried at 70ºC in the single-stage or multi-stage processes

Table 2 Effects of different treatments on total anthocyanins, total phenolics and antioxidants activity.

Treatments	Total anthocyanins (mg C3G eq/g DW)	Total phenolics (mg GAE/g DW)	Antioxidant activity (µM TE/g DW)
Fresh	14.5 ± 0.5^{a}	31.9 ± 2.1^{a}	185.5 ± 4.7^{a}
Untreated 70 °C	4.9 ± 0.9^{b}	17.5 ± 2.6^{b}	154.6 ± 5.7^{b}
Untreated 90 °C	6.2 ± 1.2^{c}	20.6 ± 0.7^{c}	159.3 ± 3.0^{c}
Untreated multistage	3.9 ± 0.5^{d}	12.3 ± 1.0^{d}	148.5 ± 4.7^{d}
pretreated 70 °C	10.6 ± 0.7^{e}	24.8 ± 1.7^{e}	164.9 ± 5.1^{d}
pretreated 90 °C	12.9 ± 0.8^{f}	$28.1. \pm 3.1^{f}$	174.4 ± 6.5^{e}
pretreated multistage	7.5 ± 0.1^{g}	24.5 ± 0.9^{e}	163.6 ± 10.6^{d}

Mean values followed by the same superscripts within the same column are not significantly different ($P<0.05$)

3.3. Colour characteristics

Mean colour values are shown in Table 3. The *L* and *a* values decreased for the dried blueberries while ***b*** value was more negative compared with the fresh sample. There was no difference in colour between dried samples**.**

Table 3 Effect of drying on the surface colour of blueberries.

Treatments	*L*	*a*	*b*
Fresh	38.41 ± 0.91^{a}	2.57 ± 0.60^{a}	-3.36 ± 0.51^{a}
Untreated 70 °C	34.61 ± 1.32^{b}	1.47 ± 0.32^{b}	-5.72 ± 0.57^{b}
Untreated 90 °C	35.83 ± 1.78^{b}	1.03 ± 0.85^{b}	-5.67 ± 0.79^{b}
Untreated multistage	34.58 ± 2.75^{b}	1.08 ± 0.93^{b}	-5.71 ± 1.06^{b}
pretreated 70 °C	36.20 ± 1.82^{b}	0.98 ± 1.09^{b}	-5.85 ± 0.42^{b}
pretreated 90 °C	35.52 ± 0.43^{b}	1.35 ± 0.74^{b}	-5.77 ± 1.53^{b}
pretreated multistage	35.81 ± 1.33^{b}	1.46 ± 0.50^{b}	-5.79 ± 1.19^{b}

Mean values followed by the same superscripts within the same column are not significantly different ($P<0.05$)

4. Discussion

4.1. Effect of pretreatment and drying temperature on drying time

Drying temperature significantly affected the moisture removal rate during drying of blueberries. Higher temperatures resulted in shorter times required to dry to specified moisture contents. Overall drying rates increased with increase in temperature for both fresh and pretreated blueberries.

Abrasive pretreatment was relatively effective in terms of drying time reduction. Total drying time decreased nearly 4 times for all drying temperatures. The results agreed with the work carried out on plums where abrasive pretreatment can markedly reduce the drying time while product quality were comparable to those that had undergone chemical pretreatment (Cinquanta et al., 2002; Di Matteo et al., 2002). However, additional research is recommended to determine optimum conditions for the process time, load and speed of the rotator. Different blueberry cultivars may require different conditions because the characteristic of their pigment-containing epidermal cell are varied (Allan-Wojtas et al., 2001). In this experiment, damage level was based on their appearance and divided into four levels as described in

Table 1. The sample that was subsequently used in the drying experiment was in level 1 or 2 in order to prevent the loss of anthocyanin pigments.

Figure 2 Blueberry appearance at level 2 damage after skin abrasive pre-treatment

Figure 3 Blueberry appearance at level 3 damage after skin abrasive pretreatment

4.2. Determination of total anthocyanins, total phenolics and antioxidant activity

During the drying process the blueberries were exposed to high temperature and air for a prolonged period of time which contributed to the loss of their antioxidants since anthocyanins are unstable in the presence of heat and oxygen (Kalt et al., 2000). Table 2 shows how different drying treatments cause loss of anthocyanins and also of phenolic content. The multi-stage drying strategy was used due to the fact that the rate of moisture removal is high at the beginning and become slower after a certain period. Thus, instead of using only one drying temperature, samples were dried at 90ºC for 90 min then at 70ºC for 120 min with a final temperature of 50ºC being used at the end of the drying treatment. The aim of using such temperature profile was to prevent blueberries from extended exposure to high temperature which can result in reduction of their antioxidant activity. However, the result revealed highest loss of antioxidants in this drying strategy especially for blueberries that had not been subjected to the abrasive pretreatment. This may explain the long drying time, 27 h, compared with 20 h and 15 h in single-stage drying tests, namely at 70ºC and 90ºC, respectively. With the aid of abrasive pretreatment, the time required to complete the drying process was similar to that used to dry at 70ºC and multistage drying (6.5 and 7 h). There was also no difference between the total phenolics and their antioxidant activity values. The results reflected that the loss of anthocyanins and phenolic compounds may be attributed mainly to the duration of drying. Thus, high temperature drying with shorter time could lessen the reduction of antioxidant activity versus using low temperature for a longer time.

4.3 Colour

Dried products had a darker colour compared to fresh blueberries indicated by their lower *L* values. The ***a*** values were lower than the fresh sample which can be explained by the degradation of the anthocyanin pigments during the drying process. It is suggested that anthocyanins can be converted to a colourless carbinol base upon heating (Nsonzi and Ramaswamy, 1998). This may also account for the more negative *b* value. Thus, dried blueberries had more bluish-brown appearance. Similar results were also found in blueberries dried with various air-drying methods studied by Nsonzi and Ramaswamy (1998) and Yang and Atallah (1985). Within the dried sample, the colour of either pretreated or untreated blueberries differed in a relatively narrow range. There was no significant trend observed visually or by using colorimeter between each drying treatments.

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