Effect of solar drier with UV-Vis filter on the antioxidant activity and anthocyanins of strawberry and blackberry pulp

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Abstract

Strawberry (Fragaria vesca) is highly prized fruit due to their beneficial health properties. The drying process is used to extend the shelf life of these fruits. However, anthocyanins are susceptible to degradation during the thermal processing, thereby reducing the quality of these food products. The objective of this study was to determine the effect of UV-Blue light filter, such as direct solar drying, on the antioxidant activity, total anthocyanins and color of strawberry pulp as the drying progressed. The UV-blue light solar filtering was obtained by using a coating of copper sulfide/copper selenide thin films of 200 nm in thickness applied on the outer surface of cellular polycarbonate sheet (8 mm cell-size, 0.1 mm wall thickness, 1 kg/m$^2$) 122 cm x 122 cm in area, and protected by a food-safe adhesive polyethylene foil. Total anthocyanins and antioxidant activity were measured using the differential method of pH and the method of DPPH (2,2-difenil-1-picrilylhidrazilo). The anthocyanin content and antioxidant capacity were better preserved in this way during drying process. The total color change was more evident in samples dried without UV-Blue light solar filter.
Keywords: solar drying, anthocyanins, berries, UV-Blue ligth filter, antioxidants.

1 Introduction

Strawberry is attractive to the consumer because of its sensory and nutritional characteristics, but it is very susceptible to spoilage by microorganisms, caused by its high moisture content. The shelf life under environmental conditions is only two to three days after harvest [1]. Therefore, drying process is important to extend the shelf life of these berries. Drying is a widely used method to increase the shelf life of foods with moisture contents above than 80%. In such drying, heat and mass transfer process are coupled involving the moisture transfer from a wet solid to a gaseous phase without saturation. The major renewable energy sources available for this drying is solar energy, available in both direct as well as indirect solar heating process [2]. Solar dryers can be used for industrial-scale drying as well [3]. The solar dryer is also can be operated as active system/forced convection, and passive system/natural convection. The most common technology used in solar drying is the direct cabinet type dryers [4]. The disadvantages of solar drying are the changing conditions inside to the drier due to weather influence, variability of sunlight, located at centers away from electric power grid, disposal and recycling of toxic residue materials, low energy efficiency in the production, and the quality of dried product affected by air pollution [5].

Also, physical, chemical and physical-chemical changes may occur in the constituents of dehydrated products. Consequently, changes in the food quality may occur, which may adversely affect the health benefit. During solar drying, a chemical defense mechanism is activated in response to stress introduced by temperature, sun light, oxygen, UV irradiation, though the synthesis of low molecular weight compounds, known as secondary metabolites [6]. The effect of UV radiation has been reported under ripening conditions: high amounts of UV radiation decrease the biomass of the plant and increase the amount of flavonoids (secondary metabolites) [7]. Similar mechanism can occur during solar drying of the berries, leading to an increase in secondary metabolites due the UV influence. Nevertheless, this increment cannot prolong indefinitely, due the adverse effect of UV on different organic materials. Thus, the effect of the UV solar filter on solar dried berries would be informative on changes brought-in on its anthocyanin content. Furthermore, the
evolution of these secondary metabolites would be of interest as well. These are thermolabile components, which can be degraded during solar drying due to thermal conditions \[8, 9, 10, 11\]

Copper sulfide selenide thin films on cellular polycarbonate sheets can supply UV-blue light filtered sunlight for on-site drying of the farm produce \[12\]. Previous results showed a better quality of color retained in solar dried apple slices due to the absence of UV in the solar radiation. Therefore, we propose applying this novel UV-blue light solar filter in solar drying of strawberries without UV-blue light influence. Thus, the main objective of this work is to evaluate the influence of the UV-blue solar filter in the preservation of secondary metabolites during solar drying of strawberry pulp.

2 Materials and methods

Raw strawberry (Fragaria vesca) were purchased at the local market and frozen at $-18^\circ$ as suggested by Feynman et al., (1964). Solar irradiance, drying temperature, filter temperature, sample temperature, color, and weight were measured during the drying at different time intervals. Samples of the fruits were also taken for chemical tests to assess the antioxidant activity, and total anthocyanins, as well as to characterize the color.

2.1 Sample preparation

Strawberries were processed into a pulp in a fruit blender. The pulp was transferred into plastic trays measuring 0.35 m x 0.50 m x 0.05 m. The layer of pulp had a thickness of 0.0315 $\pm$ 0.006 m. Four trays were occupied for this study: two for open sun drying and two for drying under the UV-Blue light filter. The sample mass for each tray was 0.9241 $\pm$ 0.2428 g.

2.2 Drying process

The samples were dried as shown in figure 1. The UV-blue light optical filter was placed above the tray. The space between the tray and the solar filter was 0.05 m. For comparison, others other two samples trays were dried directly under the sun.

Sample weight ($m$), surface temperature of the UV-blue light solar filter ($T_f$) and sample temperature on the surface ($T_s$) were periodically measured,
Figure 1: Solar drying with filter and without filter.

at time intervals of 0, 30, 60, 90, 120, 180, 240, 300 and 360 minutes. The samples were dried between 10:00 am and 5:00 pm continuously in November 2019, December 2019 and January 2020. The moisture content was calculated using the following equation (Eq.1).

\[ X_{d.b.} = \frac{(m_{hs} - m_{ds})}{m_{ds}} \]  

Where: \( X_{d.b.} \) is the Moisture content, \( m_{hs} \): Mass of the wet (humid) sample (g), \( m_{ds} \): Mass dry sample (g).

2.2.1 Drying kinetics

In the drying kinetics study we used the moisture ratio (MR) or normalized moisture content in the sample. The final recorded weight was used for equilibrium moisture content (\( X_e \)). MR was calculated using equation 2

\[ MR = \frac{(X - X_e)}{(X_0 - X_e)} \]  

Here, \( X \) is the moisture content of the sample at any drying time. \( X_0 \) is the initial moisture content.
2.3 Measurement of chemical properties

In this section, we describe the extraction procedure, total anthocyanin concentration (TA) measurement, antioxidant activity (AA) measurement. Independent samples were periodically removed from the drying tray for these chemical measurements.

2.3.1 Compound Extraction

Organic extracts (OE) were obtained from 0.5 g of sample. The liquid OE were placed in the amber vials. Three sequential extractions were performed. The fist extraction was carry out with 5 mL, the second extraction was made with 3 mL and the third was with 2 mL. we used ethanol (EtOH) acidified with 1% hydrochloric acid (HCl) for AA and methanol-water at 8:2 for TA studies. Vials with the mix were placed in an ultrasound bath during 30 min. After, we recovered the supernatant extract. The OE was filtered with Pasteur pipettes packed with cotton and stored in the refrigerator at 4°C until analysis.

2.3.2 Total anthocyanins

At intervals during the drying, samples of strawberry were taken out during drying for the determination of Total Anthocyanins (TA). The method used was the differential pH method. For this, 1.5 mL of the OE was diluted in 1.5 mL of two different buffers: 0.025 mol/L potassium chloride (KCl) of pH = 1.0 and 0.4 mol/L of sodium acetate (C₂H₃NaO₂) of pH = 4.5. Total reaction time was 30 minutes at room temperature. The measurements were made at two different wavelengths, 510 and 700 nm in the spectrophotometer (Thermo Scientific™ 840-209700, UV161Vis GENESYSTM, USA). The optical absorbance of the samples (A) was calculated using the equation 3:

\[ A = (A_{510} - A_{700})_{pH1.0} - (A_{510} - A_{700})_{pH4.5} \]  

(3)

Concentration of anthocyanins (CA in mg/L) were calculated as follows:

\[ CA = \frac{(A \ast MW \ast fd \ast 10)}{(\epsilon \ast \rho)} \]  

(4)

Where: A is the difference in absorbance between solutions of pH 1 and pH 4.5, fd: Dilution factor, \( \epsilon \): Molar absorptivity of 26900 (L / mol * cm),
MW: 449.82 (g/mol) molecular weight, p: Width of the spectrophotometer cuvette cell, of to 1 cm.

The results are expressed in mg of cyanidin 3-glucoside equivalent per g of dry solid (mg\textsubscript{C3GE} / g\textsubscript{ds}). The conversion to mg was done with adjustment 10\textsuperscript{3} with the equation 5:

\[ T_A = \frac{(CA \times V_\text{s})}{(1000 \times ds_m)} \] (5)

2.3.3 Antioxidant activity measurement

To determine the antioxidant activity (AA), a stable free radical α-diphenyl-β-picrylhydrazyl DPPH (STBG8547, Sigma-aldrich, Germany) was used. A standard curve was used for AA determinations; 2.5 mg of ascorbic acid (ACS) was weighed and diluted to 10 mL with 80% methanol. Ascorbic acid dilutions were prepared from stock solution. The entire procedure was performed in the darkness.

DPPH solution was prepared using 0.39 mg and methanol at 80%, in the darkness. Subsequently, it was placed in an ultrasonic bath during 20 minutes at room temperature. In the antioxidant activity measurement, 100 µL of each dilution of the ascorbic acid standard and 2.9 mL of DPPH solution were added to each cell. After 30 minutes at room temperature and in darkness, the lecture in an spectrophotometer (Thermo Scientific™ 840-209700, UV Vis GENESYS™, EUA) were made at= 517 nm. Similar process was made with the OE, 100 µL of the OE were added to 2.9 mL of DPPH solution. Using 80% methanol as blank. The results were expressed in mg of equivalent ascorbic acid per g of dry solid (mg\textsubscript{AAE} / g\textsubscript{ds}).

3 Results and Discussion

3.1 Optical properties

The optical transmittance (T) for a clear polycarbonate sheet and that with a copper sulfide – copper selenide UV-Blue thin film filter coating [12] are shown in figure 2. The optical transmittance of the UV-Blue light filter leads to the use of only partial quantity of solar energy during drying. This reduction in the solar energy available for the drying at the strawberry pulp
3.2 Drying kinetics

In this section, the results of the drying kinetics of strawberry pulp with and without filter, as well as the solar irradiation available for each test are discussed. The drying kinetics of strawberry is shown in figure 3. The drying time was different in each drying experiment due to the daily solar irradiation. Strawberry pulp drying with solar filter was obtained $223 \pm 59$ min and without the filter, $195 \pm 61$ min of drying time at $X = 0.15 \text{ kg}_w/\text{kg}_d$. However, the behavior of drying kinetics is the same for all experiments. The range found in solar irradiation is 300-970 W/m$^2$ during the day.
3.3 Total anthocyanins

The changes in TA during the strawberry pulp drying experiments are shown in figure 4. In each drying test, first an increase and then a decrease in TA were observed. The clear explanation of the increase in these secondary metabolites is still unknown. Enzymatic reactions can occur, leading to the formation of TA due to temperature effect and solar irradiance. The increment in anthocyanin concentration can be observed in experiments under UV-blue light filter conditions at the drying time 30 and 120 minutes. Recent reports are in agreement; there is an increase in anthocyanins during drying, possibly due to the activity of the enzyme Phenylalanine Ammonium Lisasa (PAL) in response to an increase in temperature within the berries [8, 13, 14]. On the other hand, a deterioration of the TA is noted in the pulp when the drying occurs directly under the sun. The degradation is caused by different factors such as temperature, light, oxygen [15, 16, 17]. Polyphenoloxidase (PPO) activity is the main factor responsible for the degradation of anthocyanins[18]. And in dying, anthocyanins are enzymatically degraded by PPO, a copper protein that acts on phenolic compounds, causing their oxidation and polymerization [19].

3.4 Antioxidant activity

The following figures shows the antioxidant activity of strawberry pulp dried with an without UV-blue light filter. The strawberry antioxidants are better preserved during drying with the solar filter. The figure 5 shows that AA decreases but then increase during the drying for both, with the UV-blue light filter and without it. In strawberry pulp, the increase in AA is observed at
Figure 5: Antioxidant activity of strawberry dried with and without UV-Blue light solar filter.

the beginning of drying during 30 to 180 min, but then decrease in both cases, but in general, better conserved in the pulp dried under the UV-Blue filter.

4 Conclusions

In strawberry drying kinetics with the UV-blue light filter and without it, drying is more rapid without the UV-blue light filter. With the UV-Blue filter, drying time was of 224 min and when dried directly under the sun, it was less by 30 min, 195 min to reach a dehydration of nearly 85 % of the initial pulp. Anthocyanin degradation was less with the UV-blue light solar filter in strawberry drying. In terms of antioxidant activity, the results show that without the UV-Blue light filter, the AA decreases during drying. According to the results obtained from strawberry, total anthocyanins and antioxidant activity in dried strawberry pulp obtained with the UV-blue filter is higher.

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