

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

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Abstract

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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/m²) 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-picrilhidrazilo). 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.

20 Keywords: solar drying, anthocyanins, berries, UV-Blue lighth filter, an-
21 tioxidants.

22 1 Introduction

23 Strawberry is attractive to the consumer because of its sensory and nutri-
24 tional characteristics, but it is very susceptible to spoilage by microorganisms,
25 caused by its high moisture content. The shelf life under environmental condi-
26 tions is only two to three days after harvest [1]. Therefore, drying process
27 is important to extend the shelf life of these berries. Drying is a widely used
28 method to increase the shelf life of foods with moisture contents above than
29 80%. In such drying, heat and mass transfer process are coupled involving
30 the moisture transfer from a wet solid to a gaseous phase without saturation.
31 The major renewable energy sources available for this drying is solar energy,
32 available in both direct as well as indirect solar heating process [2]. Solar
33 dryers can be used for industrial-scale drying as well [3]. The solar dryer
34 is also can be operated as active system/forced convection, and passive sys-
35 tem/natural convection. The most common technology used in solar drying
36 is the direct cabinet type dryers [4]. The disadvantages of solar drying are the
37 changing conditions inside to the drier due to weather influence, variability
38 of sunlight, located at centers away from electric power grid, disposal and
39 recycling of toxic residue materials, low energy efficiency in the production,
40 and the quality of dried product affected by air pollution [5].

41 Also, physical, chemical and physical-chemical changes may occur in the
42 constituents of dehydrated products. Consequently, changes in the food qual-
43 ity may occur, which may adversely affect the health benefit. During solar
44 drying, a chemical defense mechanism is activated in response to stress in-
45 troduced by temperature, sun light, oxygen, UV irradiation, though the syn-
46 thesis of low molecular weight compounds, known as secondary metabolites
47 [6]. The effect of UV radiation has been reported under ripening conditions:
48 high amounts of UV radiation decrease the biomass of the plant and increase
49 the amount of flavonoids (secondary metabolites) [7]. Similar mechanism can
50 occur during solar drying of the berries, leading to an increase in secondary
51 metabolites due the UV influence. Nevertheless, this increment cannot pro-
52 long indefinitely, due the adverse effect of UV on different organic materials.
53 Thus, the effect of the UV solar filter on solar dried berries would be infor-
54 mative on changes brought-in on its anthocyanin content. Furthermore, the

55 evolution of these secondary metabolites would be of interest as well. These
56 are thermolabile components, which can be degraded during solar drying due
57 thermal conditions [8, 9, 10, 11]

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

66 **2 Materials and methods**

67 Raw strawberry (*Fragaria vesca*) were purchased at the local market and
68 frozed at -18° as suggested by Feynman et al., (1964). Solar irradiance, dry-
69 ing temperature, filter temperature, sample temperature, color, and weight
70 were measured during the drying at different time intervals. Samples of the
71 fruits were also taken for chemical tests to assess the antioxidant activity,
72 and total anthocyanins, as well as to characterize the color.

73 **2.1 Sample preparation**

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

79 **2.2 Drying process**

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

84 Sample weight (m), surface temperature of the UV-blue light solar filter
85 (T_f) and sample temperature on the surface (T_s) were periodically measured,

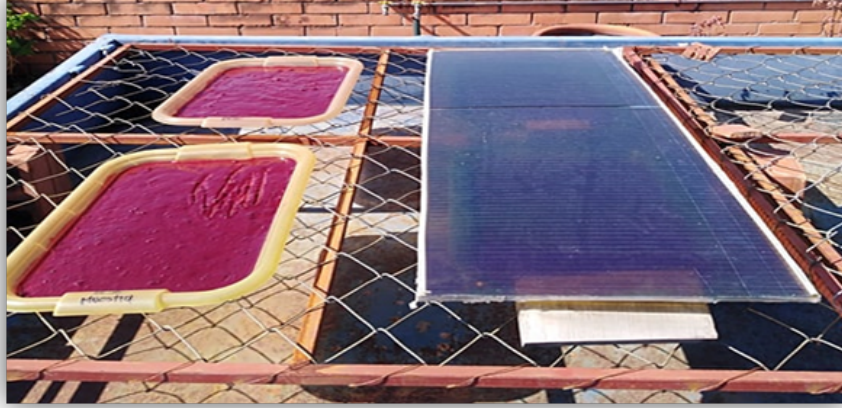


Figure 1: Solar drying with filter and without filter.

86 at time intervals of 0, 30, 60, 90, 120, 180, 240, 300 and 360 minutes. The
 87 samples were dried between 10:00 am and 5:00 pm continuously in November
 88 2019, December 2019 and January 2020. The moisture content was calculated
 89 using the following equation (Eq.1).

$$X_{d.b.} = \frac{(m_{hs} - m_{ds})}{m_{ds}} \quad (1)$$

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

92 2.2.1 Drying kinetics

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

$$MR = \frac{(X - X_e)}{(X_0 - X_e)} \quad (2)$$

96 Here, X is the moisture content of the sample at any drying time. X_0 is
 97 the initial moisture content.

98 **2.3 Measurement of chemical properties**

99 In this section, we describe the extraction procedure, total anthocyanin con-
100 centration (TA) measurement, antioxidant activit (AA) measurement. Inde-
101 pendent samples were periodically removed from the drying tray for these
102 chemical measurements.

103 **2.3.1 Compound Extraction**

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

113 **2.3.2 Total anthocyanins**

114 At intervals during the drying, samples of strawberry were taken out during
115 drying for the determination of Total Anthocyanins (TA). The method used
116 was the differential pH method. For this, 1.5 mL of the OE was diluted in
117 1.5 mL of two different buffers: 0.025 mol/L potassium chloride (KCl) of
118 pH = 1.0 and 0.4 mol/L of sodium acetate ($C_2H_3NaO_2$) of pH = 4.5. Total
119 reaction time was 30 minutes at room temperature. The measurements were
120 made at two different wavelengths, 510 and 700 nm in the spectrophotome-
121 ter (Thermo Scientific™ 840-209700, UV161Vis GENESYS™, USA). The
122 optical absorbance of the samples (A) was calculated using the equation 3:

$$A = (A_{510} - A_{700})_{pH_{1.0}} - (A_{510} - A_{700})_{pH_{4.5}} \quad (3)$$

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

$$CA = \frac{(A * MW * fd * 10)}{(\epsilon * \rho)} \quad (4)$$

124 Where: A is the difference in absorbance between solutions of pH 1 and
125 pH 4.5, fd: Dilution factor, ϵ : Molar absorptivity of 26900 (L / mol * cm),

126 MW: 449.82 (g / mol) molecular weight, p: Width of the spectrophotometer
127 cuvette cell, of to 1 cm.

128 The results are expressed in mg of cyanidin 3-glucoside equivalent per g
129 of dry solid ($\text{mg}_{C3GE} / \text{g}_{ds}$). The conversion to mg was done with adjustment
130 10_3 with the equation 5:

$$T_A = \frac{(CA * V_s)}{(1000 * ds_m)} \quad (5)$$

131 2.3.3 Antioxidant activity measurement

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

138 DPPH solution was prepared using 0.39 mg and methanol at 80%, in
139 the darkness. Subsequently, it was placed in an ultrasonic bath during 20
140 minutes at room temperature. In the antioxidant activity measurement,
141 100 μL of each dilution of the ascorbic acid standard and 2.9 mL of DPPH
142 solution were added to each cell. After 30 minutes at room temperature and
143 in darkness, the lecture in an spectrophotometer (Thermo Scientific™ 840-
144 209700, UV Vis GENESYS™, EUA) were made at= 517 nm. Similar process
145 was made with the OE, 100 μL of the OE were added to 2.9 mL of DPPH
146 solution. Using 80% methanol as blank. The results were expressed in mg of
147 equivalent ascorbic acid per g of dry solid ($\text{mg}_{AAE} / \text{g}_{ds}$).

148 3 Results and Discussion

149 3.1 Optical properties

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

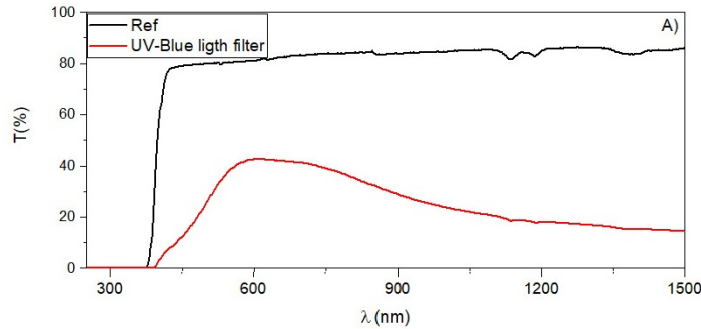


Figure 2: A) Optical transmittance(T) of polycarbonate sheet(Ref) and with copper chalcogenide coatings of thickness 160 nm (UV-Blue light filter), deposited by flotation by chemical deposition.

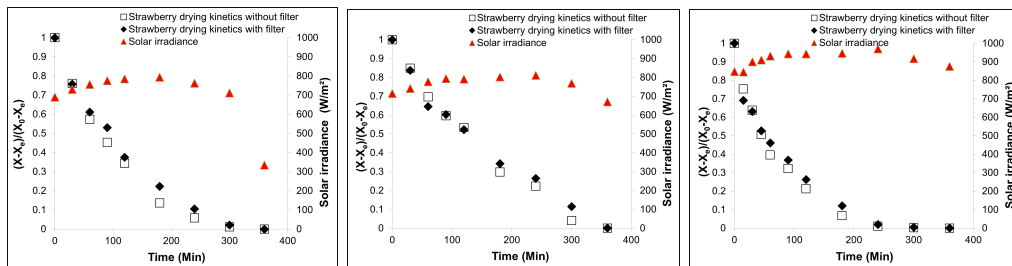


Figure 3: Drying kinetics of 3 experiments using a UV-Blue light filter.

155 influences the drying rate and the time required to reach a certain moisture
 156 content in the product.

157 3.2 Drying kinetics

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

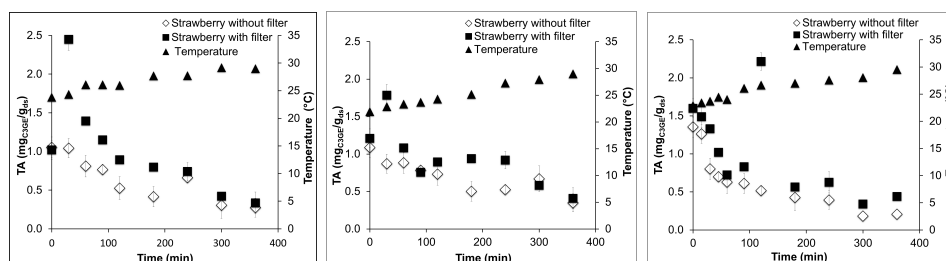


Figure 4: Total anthocyanin content of strawberry pulp dried using a UV-Blue light filter.

166 3.3 Total anthocyanins

167 The changes in TA during the strawberry pulp drying experiments are shown
 168 in figure 4. In each drying test, first an increase and then a decrease in TA
 169 were observed. The clear explanation of the increase in these secondary
 170 metabolites is still unknown. Enzymatic reactions can occur, leading to the
 171 formation of TA due to temperature effect and solar irradiance. The in-
 172 crement in anthocyanin concentration can be observed in experiments under
 173 UV-blue light filter conditions at the drying time 30 and 120 minutes. Recent
 174 reports are in agreement; there is an increase in anthocyanins during dry-
 175 ing, possibly due to the activity of the enzyme Phenylalanine Ammonium
 176 Liasa (PAL) in response to an increase in temperature within the berries
 177 [8, 13, 14]. On the other hand, a deterioration of the TA is noted in the pulp
 178 when the drying occurs directly under the sun. The degradation is caused
 179 by different factors such as temperature, light, oxygen [15, 16, 17]. Polyphe-
 180 noloxidase (PPO) activity is the main factor responsible for the degradation
 181 of anthocyanins[18]. And in dying, anthocyanins are enzymatically degraded
 182 by PPO, a copper protein that acts on phenolic compounds, causing their
 183 oxidation and polymerization [19].

184 3.4 Antioxidant activity

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

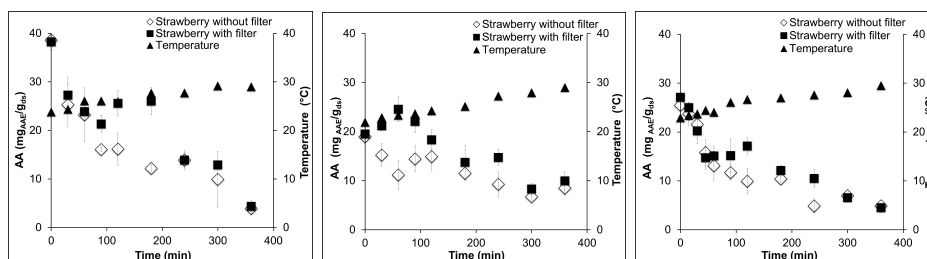


Figure 5: Antioxidant activity of strawberry dried with and without UV-Blue light solar filter.

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

193 4 Conclusions

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

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