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Effect of Blanching, Drying and Storage to Cinnamic Acid and Antioxidant Activity on Dried Strawberry (*Fragaria*)

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Abstract.

Strawberries (*Fragaria*), a rich source of phytochemicals (ellagic acid, anthocyanins, quercetin, and catechin) and vitamins (ascorbic acid and folic acid), have been highly ranked among dietary sources of polyphenols and antioxidant capacity. Bioactive compounds in strawberry revealed high abundance of anthocyanins, flavonols, flavanols, and cinnamic acid. To increase strawberrys popularity and expand their use in the food industry, it's neccesary to explore the appropriate postharvest handling and storage. Therefore, objective of this study focused on the effect of blanching temperature and time; heat pump drying temperature and storage condition to cinnamic acid (mg/100 g_{DW}), antioxidant activity (mmol·Fe^{2+}/kg_{DW}), color (sensory score) of the dried strawberry *(Fragaria)* . Results showed that strawberry *(Fragaria)* should be blanched in hot water 95°C at 10 seconds in the present of Calcium lactate 0.2% and then beeing dried by heat pump dryer at 50°C until 12% moisture. The final dried strawberry could be preserved under vacuum in PET/AL/PE bag at 4°C to maintain antioxidant activity for 12 months.

Keywords: *Strawberry, Fragaria, blanching, drying, antioxidant activity*

I. INTRODUCTION

Strawberry, a member of the Rosaceae family that belongs to the genus *Fragaria*, is very popular due to its attractive fruits with unique taste, spectacular aroma, and smooth red texture. Strawberry contains high levels of micronutrients and phytochemical compounds. These exhibit functional roles in plant growth and metabolism and are also essential for the nutritional and organoleptic qualities of the fruit.[1] The nutritional quality ofstrawberry fruits correlates with the remarkable abundance of phenolic compounds, including anthocyanin, flavonoids, and nutrients such as folate, vitamin C, sugars, and minerals.[2, 3] Strawberry fruitsrich in phenolic compounds can impart health benefits to humans.[4] The characteristic phenolic compounds in strawberries are anthocyanins, which are responsible for the red flesh color, flavonols, flavanols, and derivatives of hydroxycinnamic and ellagic acid. The free radical scavenging effect of the fruit extract can be associated with the anthocyanin content.[5] Strawberries are the main dietary source of ellagic acid-containing compounds, such as ellagic acid and ellagitannins, which account for 51% of their total phenolic content.[6] The remarkable polyphenolic and antioxidant contents of strawberries improve the immune system and reduce obesity-related disorders and the risk of heart disease.[7, 8] Moreover, it has been shown that strawberry fruit extracts exhibit antioxidative and anticancer activities both and in vivo. the bioavailability and metabolism of major strawberry phytochemicals as well as their actions in combating many pathologies, including cancer, metabolic syndrome, cardiovascular disease, obesity, diabetes, neurodegeneration, along with microbial pathogenesis have been reviewed.[7] Consumption of strawberries has several other health benefits, such as improved eye condition, enhanced brain function, and relief from high blood pressure, arthritis, and various cardiovascular diseases.[7] Nutritional epidemiology shows inverse association between strawberry consumption and incidence of hypertension or serum C-reactive protein; controlled feeding studies have identified the ability of strawberries to attenuate high-fat diet induced postprandial oxidative stress and inflammation, or postprandial hyperglycemia, or hyperlipidemia in subjects with cardiovascular risk factors.[9] The nutritional quality of strawberry fruits can be considerably affected by several pre-harvest and post-harvest conditions, which, in most cases, may decrease the nutrient and the phytochemical contents of this fruit.[10]

Drying kinetic, as well as color and volume variation, of whole and sliced strawberries were investigated after freezedrying under various temperatures (30, 40, 50, 60 and 70°C).[11] The effects of different drying conditions, such as infrared power, drying air temperature and velocity, on quality of strawberry were evaluated.[12] The effect of blanching and glucose concentration before drying on the rate of moisture movement during the early stages of air dehydration of strawberries at 55 °C was studied.[13] The effect of water or steam blanching, glucose impregnation to attain an equilibrium water activity (a_w) value of 0.93 or 0.95, and the addition of calcium on textural characteristics of strawberries was analysed.[14] Processing, packaging, and storage effects on quality of freeze-dried strawberries were determined.[15] Strawberries are highly susceptible to mechanical injury, physiological disorders, fungal activity and water loss.[16] They have a very short post harvest shelf life, which effects market potential and consumer access.[17] The cultivation and awareness of the numerous benefits of strawberry *(Fragaria)* is springing up in Vietnam and there arise the need to produce value-added products. To increase strawberrys popularity and expand their use in the food industry, it's neccesary to explore the appropriate postharvest handling and storage. Therefore, objective of this study focused on the effect of blanching temperature and time; heat pump drying temperature and storage condition to cinnamic acid (mg/100 g_{DW}), antioxidant activity (mmol·Fe^{2+}/kg_{DW}), color (sensory score) of the dried strawberry *(Fragaria)*.

II. MATERIALS AND METHOD

2.1 Material

We collected strawberry *(Fragaria)* in Lam Dong province, Vietnam. They must be cultivated following VietGAP to ensure food safety. After collecting, they must be conveyed to laboratory within 4 hours for experiments. They were washed under tap water to remove foreign matters. The samples were then washed with Perasan to avoid contamination. After removing the superficial green portion, the fruits were subsequently blanched and dried. Besides strawberry *(Fragaria)* we also used another material during the research such as Calcium lactate. Lab utensils and equipments included digital weight balance, cooker, heat pump dryer.

Figure 1. Strawberry *(Fragaria)*

2.2 Researching procedure

2.2.1 Effect of blanching temperature and time to cinnamic acid (mg/100 g_{DW}), antioxidant activity (mmol·Fe^{2+}/kg_{DW}) and color (sensory score) in the dried strawberry (Fragaria)

Raw strawberry *(Fragaria)* were blanched in water solution with 0.2% Calcium lactate at different temperature and time (100°C, 5 second; 95°C, 10 seconds; 90°C, 15 seconds; 85°C, 20 seconds). Then they were dried by heat pump at 50°C until 12% moisture. All samples were analyzed cinnamic acid (mg/100 g_{DW}), antioxidant activity (mmol·Fe^{2+}/kg_{DW}), color (sensory score) to validate the appropriate blanching condition.

2.2.2 Effect of drying temperature by heat pump to cinnamic acid (mg/100 g_{DW}), antioxidant activity (mmol·Fe^{2+}/kg_{DW}) and color (sensory score) in the dried strawberry (Fragaria)

Raw strawberry *(Fragaria)* was blanched in water solution with 0.2% Calcium lactate at 95°C in 10 seconds. Then these samples would be dried under heat pump dryer at different temperature (30°C, 35°C, 40°C, 45°C, 50°C, 55°C) until 12% moisture. All samples were analyzed cinnamic acid (mg/100 g_{DW}), antioxidant activity (mmol·Fe^{2+}/kg_{DW}), color (sensory score) to validate the appropriate drying temperature.

2.2.3 Effect of storage condition to antioxidant activity (mmol·Fe^{2+}/kg_{DW}) in the dried strawberry (Fragaria)

After completion of drying treatment, the dried strawberry *(Fragaria)* was subjected to storage. They were kept in PET/AL/PE (zipper top), PET/AL/PE (vaccum) bag at different 4°C, 28°C. The antioxidant activity (mmol·Fe^{2+}/kg_{DW}) will be analyzed in 3 months interval for 12 months.

2.3 Physico-chemical and sensory analysis

Cinnamic acid **(**mg/100 g_{DW}) content of the strawberry *(Fragaria)* was determined by chromatographic method.[18] The antioxidant capacity of strawberry was assessed using a ferric reducing antioxidant power (FRAP) assay.[19, 20] Color (sensory score) of strawberry (*Fragaria)* was assessed by a group of panelist. They were required to evaluate the odour, colour, taste, sweetness and overall acceptance using the 9-point hedonic scale (1 = dislike extremely, 9 = like extremely).

2.4 Statistical analysis

The experiments were run in triplicate with three different lots of samples. Data were subjected to analysis of variance (ANOVA) and mean comparison was carried out using Duncan's multiple range test (DMRT) Statistical analysis was performed by the Startgraphics.

III. RESULT & DISCUSSION

3.1 Effect of blanching temperature and time to cinnamic acid (mg/100 g_{DW}), antioxidant activity (mmol·Fe^{2+}/kg_{DW}) and color (sensory score) in the dried strawberry *(Fragaria)*

Raw strawberry *(Fragaria)* was blanched in water solution with 0.2% Calcium lactate at different temperature and time (100°C, 5 second; 95°C, 10 seconds; 90°C, 15 seconds; 85°C, 20 seconds). Then they were dried by heat pump at 50°C until 12% moisture. All samples were analyzed cinnamic acid (mg/100 g_{DW}), antioxidant activity (mmol·Fe^{2+}/kg_{DW}), color (sensory score) to validate the appropriate blanching condition. Results were mentioned in table 1. From table 1, the strawberry *(Fragaria)* should be blanched at 95°C in 15 seconds to maintain the most cinnamic acid (mg/100 g_{DW}), antioxidant activity (mmol·Fe^{2+}/kg_{DW}), and sensory score in the dried *strawberry (Fragaria)* .

The effect of blanching and glucose concentration before drying on the rate of moisture movement during the early stages of air dehydration of strawberries at 55 °C was studied. It was found that the effective diffusion coefficient of water in strawberries (D_{eff}) was strongly affected by heat pretreatment, but glucose dipping after blanching caused no additional effect.[13] The effect of water or steam blanching, glucose impregnation to attain an equilibrium water activity (a_w) value of 0.93 or 0.95, and the addition of calcium on textural characteristics of strawberries was analysed. Strawberries were softened by blanching, varying the maximum extrusion force from 53 to 82% of the value of the fresh fruit for water or vapour treatment, respectively. Major changes in texture occurred during blanching, while the influence of the impregnation step depended on the previous treatment. Addition of 0.1% (w/w) calcium lactate during the impreg nation stage improved the textural characteristics of vapour-blanched glucose-treated fruits but was ineffective in preventing softening of water-blanched glucose-treated strawberries.[14]

3.2 Effect of drying temperature by heat pump to cinnamic acid (mg/100 g_{DW}), antioxidant activity (mmol·Fe^{2+}/kg_{DW}) and color (sensory score) in the dried strawberry *(Fragaria)*

Drying is particularly important for handling and distribution of agricultural products with high moisture content and limited shelf life such as fruits and vegetables. The main objective of drying is to reduce moisture content to a level where microbial spoilage and deteriorative chemical reactions of agricultural products in minimal.[21] Drying is one of the oldest methods of food preservation during which strawberries must be protected against direct solar radiation to avoid discoloration. Drying techniques also cause changes in some physical properties, such as color, texture, and size. Chemical changes, such as losses of flavor and nutrients, also occur during convective drying.[22]

Raw strawberry *(Fragaria)* was blanched in water solution with 0.2% Calcium lactate at 95°C in 10 seconds. Then these samples would be dried under heat pump dryer at different temperature (30°C, 35°C, 40°C, 45°C, 50°C, 55°C) until 12% moisture. All samples were analyzed cinnamic acid (mg/100 g_{DW}), antioxidant activity (mmol·Fe^{2+}/kg_{DW}), color (sensory score) to validate the appropriate drying temperature. Results were mentioned in table 2. From table 2, they should be dried at 50°C to maintain the most cinnamic acid (mg/100 g_{DW}), antioxidant activity (mmol·Fe^{2+}/kg_{DW}) and sensory score in the dried strawberry *(Fragaria)* .

At heating temperatures higher than 50°C, the strawberry dry layer temperature was higher than the estimated glass transition temperature of dried fruit, increasing the risk of collapse.[11] The effects of different drying conditions, such as infrared power, drying air temperature and velocity, on quality of strawberry were evaluated. The optimal conditions to preserve nutrients in infrared drying of strawberry were 200 W, 100 □C and 1.5 m/s).[12] It was observed that ellagic acid and flavanol in strawberry were adversely affected by drying techniques.[23]

3.3 Effect of storage condition to antioxidant activity (mmol·Fe^{2+}/kg_{DW}) in the dried strawberry *(Fragaria)*

After completion of drying treatment, the dried strawberry *(Fragaria)* was subjected to storage. They were kept in PET/AL/PE (zipper top), PET/AL/PE (vaccum) bag at different 4°C, 28°C. The antioxidant activity (mmol·Fe^{2+}/kg_{DW}) will be analyzed in 3 months interval for 12 months. Dried strawberry *(Fragaria)* should be stored under vacuum in PET/AL/PE bag at 4°C to maintain antioxidant activity (mmol·Fe^{2+}/kg_{DW}) for 12 months.

Table 1. Effect of blanching and time to cinnamic acid (mg/100 g_{DW}), antioxidant activity (mmol·Fe^{2+}/kg_{DW}) and color (sensory score) in the dried strawberry *(Fragaria)*

Blanching	Cinnamic acid (mg/100 g_{DW})	Antioxidant activity (mmol·Fe^{2+}/kg_{DW})	Sensory score
100°C, 5 seconds	57.45±0.02^{b}	8.07±0.02^{b}	6.65±0.01^{c}
95°C, 10 seconds	60.38±0.01^{a}	9.41±0.01^{a}	7.29±0.02^{a}
90°C, 15 seconds	56.01±0.00^{c}	6.64±0.00^{c}	7.04±0.01^{b}
85°C, 20 seconds	52.67±0.01^{d}	5.71±0.03^{d}	6.12±0.01^{d}

Note: the values were expressed as the mean of three repetitions; the same characters (denoted above), the difference between them was not significant (α = 5%).

Table 2. Effect of drying temperature by heat pump to cinnamic acid (mg/100 g_{DW}), antioxidant activity (mmol·Fe^{2+}/kg_{DW}) and color (sensory score) in the dried strawberry *(Fragaria)*

Drying temperature	Cinnamic acid (mg/100 g_{DW})	Antioxidant activity (mmol·Fe^{2+}/kg_{DW})	Sensory score
30°C	59.85±0.03^{ab}	9.40±0.01^{a}	7.08±0.02^{b}
35°C	59.85±0.00^{ab}	9.40±0.03^{a}	7.08±0.01^{b}
40°C	59.83±0.01^{ab}	9.40±0.02^{a}	7.10±0.03^{ab}
45°C	59.80±0.02^{ab}	9.41±0.01^{a}	7.13±0.02^{ab}
50°C	**60.38±0.01^{a}**	**9.41±0.01^{a}**	**7.29±0.02^{a}**
55°C	52.27±0.02^{b}	8.05±0.03^{b}	6.55±0.01^{c}

Note: the values were expressed as the mean of three repetitions; the same characters (denoted above), the difference between them was not significant (α = 5%).

Table 3. Antioxidant activity (mmol·Fe^{2+}/kg_{DW}) in dried strawberry *(Fragaria)* by the effect of packaging material and storage temperature

Storage time (month)	Dried strawberry *(Fragaria)* by the storage temperature (°C) kept in PET/AL/PE (zipper top)		Dried strawberry *(Fragaria)* by the storage temperature (°C) kept in PET/AL/PE (vaccum)	
	4 °C	28 °C	4 °C	28 °C
0	9.41±0.01^{a}	9.41±0.01^{a}	9.41±0.01^{a}	9.41±0.01^{a}
3	9.37±0.02^{ab}	9.36±0.00^{ab}	9.40±0.01^{a}	9.38±0.02^{ab}
6	9.36±0.00^{ab}	9.32±0.02^{b}	9.38±0.01^{ab}	9.35±0.00^{b}
9	9.29±0.01^{b}	9.27±0.01^{bc}	9.35±0.03^{ab}	9.30±0.01^{bc}
12	9.26±0.03^{b}	9.25±0.03^{c}	9.29±0.01^{b}	9.27±0.03^{c}

Note: the values were expressed as the mean of three repetitions; the same characters (denoted above), the difference between them was not significant (α = 5%).

A study was to determine how vacuum-assisted microwave drying (VMD, 50C, 6 kPa for 3 h) affects the quality attributes and shelf life of dehydrated strawberries. Changes of quality attributes such as color, texture, and rehydration, shrinkage, polyphenol contents, antioxidant activity, and physicochemical and sensory properties were assessed. Vacuum packed, dehydrated strawberries were stored at 20^{o}C in the dark for 6 months. VMD resulted to minimum color difference. Texture changed by increased mechanical resistance and stiffness, and decreased toughness after VMD. Sensory attributes were between 3.5 and 4.3 on 5-point intensity hedonic scale. Anthocyanins were the most unstable components in strawberries after VMD and storage, assessing the strawberry shelf life to 68 days.[21] In another research, water sorption isotherms of freeze-dried strawberries were determined using the interval sorption technique. The surface temperature during freeze-drying (from 20°C to 60°C) affected the hygroscopicity of the strawberries, particularly below 0.40 a_w. Over 1 year, quality changes in dried strawberries were evaluated by sensory analysis at 3-month intervals. Crushing before drying and low processing temperatures improved sensory quality of dried strawberries and vacuum packaging improved storage stability.[15]

IV. CONCLUSION

Dried strawberry (*Fragaria*) is referred to as a functional fruit because of its high nutritional value and bioactive elements. These bioactive factors can be significantly affected by differences in strawberry cultivars, agricultural practices, storage, and processing methods. Dehydration preserves strawberry in a stable and safe condition by reducing water activity, extending the shelf life much longer than that of fresh products.

REFERENCES

1. Sara Tulipani, Bruno Mezzetti, Franco Capocasa, Stefano Bompadre, Jules Beekwilder, C. H. Ric de Vos, Esra Capanoglu, Arnaud Bovy and Maurizio. Battino. Antioxidants, phenolic compounds, and nutritional quality of different strawberry genotypes. *J. Agric. Food Chem.* 2008; *56* (3): 696–704.
2. Forbes-Hernandez TY, Gasparrini M, Afrin S, Bompadre S, Mezzetti B, Quiles JL, Giampieri F, Battino M. The healthy effects of strawberry polyphenols: which strategy behind antioxidant capacity. *Crit Rev Food Sci Nutr* 2016; 56:S46-S59.
3. Giampieri F, Tulipani S, Alvarez-Suarez JM, Quiles JL, Mezzetti B, Battino M. The strawberry: Composition, nutritional quality, and impact on human health. *Nutrition* 2012; 28:9-19.
4. Giampieri F, Alvarez-Suarez JM, Battino M. Strawberry and human health: effects beyond antioxidant activity. *J Agric Food Chem* 2014; 62: 3867-3876.
5. José Cheel, Cristina Theoduloz, Jaime Rodríguez, Guillermo Saud, Peter D. S. Caligari, and Guillermo Schmeda-Hirschmann. *E*-Cinnamic Acid Derivatives and Phenolics from Chilean Strawberry Fruits, *Fragaria chiloensis* ssp. *Chiloensis. J. Agric. Food Chem.* 2005; *53*(22): 8512–8518.
6. Häkkinen SH, Kärenlampi SO, Mykkänen HM, Heinonen IM, Törrönen AR. Ellagic acid content in berries: Influence of domestic processing and storage. *Eur Food Res Technol* 2000; 212:75-80.
7. Afrin S, Gasparrini M, Forbes-Hernandez TY, Reboredo-Rodriguez P, Mezzetti B, Varela-López A, Giampieri F, Battino M. Promising health benefits of the strawberry: A focus on clinical studies. *J Agric Food Chem* 2016; 64:4435-4449.
8. Elena Azzini, Paola Vitaglione, Federica Intorre, Aurora Napolitano. Bioavailability of strawberry antioxidants in human subjects. *British Journal of Nutrition* 2010; 104(8): 1165-1173.
9. Arpita Basu, Angel Nguyen, Nancy M. Betts & Timothy J. Lyons. Strawberry as a functional food: an evidence-based review. *Critical Reviews in Food Science and Nutrition* 2014; 54(6): 790-806.
10. Alvarez-Suarez, Josè M., Mazzoni, Luca, Forbes-Hernandez, Tamara Y., Gasparrini, Massimiliano, Sabbadini, Silvia, Giampieri, Francesca. The effects of pre-harvest and post-harvest factors on the nutritional quality of strawberry fruits: A review. *Journal of Berry Research* 2014; 4(1): 1-10.
11. F. Shishehgarha, J. Makhlouf, and C. Ratti. Freeze-drying characteristics of strawberries. *Drying Technology* 2002; 20(1): 131–145.
12. Nafiye Adak, Nursel Heybeli, Can Ertekin. Infrared drying of strawberry. *Food Chemistry* 2017; 219: 109–116.
13. C.A.Alvarez, R.Aguerre, R.Gómez, S.Vidales, S.M.Alzamora, L.N.Gerschenson. Air dehydration of strawberries: Effects of blanching and osmotic pretreatments on the kinetics of moisture transport. *Journal of Food Engineering* 1995; 25(2): 167-178.
14. S.L. Vidales, M.A. Castro, S.M. Alzamora. The structure-texture relationship of blanched and glucose-impregnated strawberries. *Food Science and Technology International* 1998; 4(3): 169-178.
15. K. Pääkkönen, M. Mattila. Processing, packaging, and storage effects on quality of freeze-dried strawberries. *Journal of Food Science* 1991; 56(5): 1388-1392.
16. Romanazzi, G., Feliziani, E., Santini, M., & Landi, L. Effectiveness of postharvest treatment with chitosan and other resistance inducers in the control of storage decay of strawberry. *Postharvest Biology and Technology* 2013; 75, 24–27.
17. Aday, M. S., & Caner, C. Individual and combined effects of ultrasound, ozone and chlorine dioxide on strawberry storage life. *LWT-Food Science and Technology* 2014; 57: 344–351.
18. D. Donno, G. L. Beccaro, M. G. Mellano, L. Bonvegna, and G. Bounous. Castanea spp. buds as a phytochemical source for herbal preparations: botanical fingerprint for nutraceutical identification and functional food standardization. *Journal of the Science of Food and Agriculture* 2014; 94(14): 2863–2873.
19. I. F. Benzie and J. J. Stain. Ferric reducing/antioxidant power assay: direct measure of total antioxidant activity of biological fluids and modified version for simultaneous measurement of total antioxidant power and ascorbic concentration. *Methods in Enzymology* 1999; 299: 15–27.
20. R. Pulido, L. Bravo, and F. Sauro-Calixto. Antioxidant activity of dietary polyphenols as determined by a modified ferric reducing/antioxidant power assay. *Journal of Food Chemistry* 2000; 48: 3396–3402.
21. Johannes de Bruijn, Fernando Rivas, Yeaninna Rodriguez, Cristina Loyola, Adan Flores, Pedro Melin, Rodrigo Borquez. Effect of vacuum microwave drying on the quality and storage stability of strawberries. *Journal of Food Processing and Preservation* 2016; 40(5): 1104-1115.
22. Krokida, M. K., & Marinos-Kouris, D. Rehydration kinetics of dehydrated products. *Journal of Food Engineering* 2003; 57: 1–7.
23. Wojdylo, A., Figiel, A., & Oszmianski, J. Effect of drying methods with the application of vacuum microwaves on the bioactive compounds, color, and antioxidant activity of strawberry fruits. *Journal of Agricultural and Food Chemistry* 2009; 57: 1337–1343.