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THE EFFECT OF CONVECTIVE FIXED BED DRYING BASED ON A SOLAR COLLECTOR AND PHOTOVOLTAIC (CSD) TO THE QUALITY ATRIBUTES OF RED PEPPER COMPARED WITH CONVENTIONAL CONVECTIVE FIXED BED DRYING (CCD)

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ABSTRACT

The effect of conventional convective drying (CCD) and convective solar drying (CSD) based on a solar collector and photovoltaic on the quality of dried red pepper was researched. The study was aimed to determine the effect of five drying system (CCD 50°C, CCD 60°C, CCD 70°C, CSD, and open sun drying) on the quality attributes of dried red pepper. The quality observed were rehydration ratio, ascorbic acid, capsaicin, non-enzymatic browning index, anthocyanin, and carotenoids. The results of the study confirmed that the drying system significantly affected the quality attributes of dried red pepper except for anthocyanin. The CSD had a satisfactory result, shown by some attributes (carotenoids, ascorbic acid, and ratio) which were not statistically different from the quality of dried red pepper gained from CCD 50°C.

Keywords: *convective drying, fixed bed, quality atributes, red pepper*

INTRODUCTION

Red pepper (*Capsicum annum*) is a high economic commodity that has a quite perishable character (Adedeji *et al.*, 2008; (Hossain & Bala, 2007); (Montoya-Ballesteros, *et al.*, 2014); (Deng *et al.*, 2018). Drying activity is the most common methods to prolong the storage period of red pepper (Xiao & Mujumdar, 2014). Convective drying is popular for agricultural products, due to its high effectiveness, convenient application and low operating costs (Zielinska & Markowski, 2016). (Adedeji, *et al.*, 2008) mentioned that in a hot air drying, the heat and mass transfer system of the dried materials could be managed to achieve the satisfactory quality. In a fixed convective drying, hot air passes through the layers of the material at a particular speed for a precise time, until it reaches a secure water content. However, this system is high energy demand, so it is not suitable to be applicated in rural areas.

An alternative drying system using solar energy which has a similar concept with hot air convective drying was studied in this research. According to (Hossain & Bala, 2007), the using of solar dryer has a good prospect to be developed primarily at the household level with the drying capacity of 10-15 kg. Because natural convective solar dryers are still susceptible to fungal attacks due to unstable temperature and humidity, developing an affordable forced convective solar drying is essential to do.

Heat is an essential aspect that affects the quality of the dried product of a particular drying process. A prolonging of thermal exposure on red peppers will cause severe nutrient degradation (Vega-Gálvez *et al.*, 2009); (Vega-Gálvez, *et al.*, 2012). The other factors that affect the quality of the dried product are relative humidity, drying duration, air flow index and the drying thickness (Veras, Béttega, Freire, Barrozo, & Freire, 2012); (Marques, *et al.*, 2009). Inappropriate environmental conditions will reduce the nutritional content of agricultural products (Maskan, 2001); (Adedeji *et al.*, 2008). As each agrarian commodity is unique, its behavior throughout drying is also distinctive to every product. (Di Scala & Crapiste, 2008) explained that there is an 82-88 % reduction in ascorbic acid content in the convective drying of red peppers. (Tunde-Akintunde, *et al.*, 2014) who carried out a convective drying on red peppers also showed similar results. The other quality attributes of dried red peppers are non-enzymatic browning index, anthocyanins, carotenoids, and rehydration ratio. The rehydration ratio indicates the texture of injury in a drying process. The higher the rehydration ratio, the better functioning of hydrophilic properties in absorbing water (Vega-Gálvez *et al.*, 2009); (Marques *et al.*, 2009).

(Prakash, *et al.*, 2004) said that the solar drying cabinet produces dried slice carrot with a high content of beta-carotene, but it has a low rehydration ratio and a high percentage of shrinkage. (Bechoff *et al.*, 2010) demonstrated that there is no significant loss of total beta-carotene in sweet potato dried with a greenhouse solar dryer. (Chen, *et al.*, 2005) which conducted a drying research of lemon slices using solar dryers equipped with photovoltaic modules, explained that the brightest color of lemon was obtained in the range of drying temperature of 36-50° C. It is better than the results of oven drying.

Meanwhile, in the drying of grapes with solar dryer, directly and indirectly, a decrease in vitamin C is significant, but the color change is acceptable to consumers. (Banout, *et al.*, 2010) said that drying with direct solar dryer produces dried long coriander leaves with poor quality, due to the uncontrolled browning process. While in an indirect solar drying it resulted a better quality of dried coriander leaves. Drying with solar energy has a potential to develop to produce high quality dried fruits and vegetables.

For the best of our knowledge, investigations that are comparing conventional convective drying and convective olar drying to get high quality of dried red pepper is still limited. This research is aimed to study the effect of convective fixed bed drying based on a solar collector and photovoltaic (CSD) to the quality atributes value of dried pepper quality compared to conventional convective fixed bed drying (CCD).

MATERIALS AND METHODS

Materials

The fresh red pepper was bought at a nearby market in Malang, Indonesia. The red peppers were selected manually with the following criteria: no visible mechanical injury and homogenous in color and size. The weight was 20-25 g each with 80-85% moisture content. The red peppers were harvested in the close by plantations at night before the implementation of drying.

Drying Implementation

The Conventional Convective Drying was carried out in Post-Harvest and Food Processing Laboratory of Brawijaya University in May-August 2017, and the Convective Solar Drying (CSD) process was carried out in Experiment Field of Agriculture Faculty, University of Islam Malang. The dryer used was a convective fixed bed dryer designed by (Sutherland, *et al.*, 1971) and Convective Solar Drying designed in Brawijaya University and University of Islam Malang. The CCD consists of a blower, an electrically powered heater, a voltage regulator, and a column drying chamber. The drying chamber consists of 5 layers with 200-250 grams capacity of red pepper for each layers. The layer has a perforated bottom in a size of 20 mesh. Drying was carried out at each temperature (50°, 60°, and 70°C) until the water content of the red peppers reached 12-13%. The red peppers were positioned in the dryer column on a stacked layer. Each layer represents a thin layer at different heights. The repetition was accomplished two times. The air flow used was 1.8 m/s. The drying time was between 20-50 hours relies upon the temperature and the layer position.

The convective solar dryer (CSD) is supported by a collector, a solar photovoltaic, a drying unit in a silo model with five layers and a blower. The blower has a maximum voltage: 24 volts and maximum speed: 3 m/s. It also consists of 5 layers, with 1 kg of red pepper capacity for each layer. The drying implementation was done by 07.30-16.30 (9 hours a day).

Quality Analysis

Quality analysis of dried red pepper was done in Agricultural Physiology Laboratory, Agriculture Faculty, University of Islam Malang. The analysis was done on anthocyanin, carotenoids, ascorbic acid, capsaicin, rehydration ratio,and non enzymatic browning index.

Anthocyanin

Anthocyanin analyzes were performed by extracting ± 1 gram of sample powder with 5% HCl solution (1:10) in dark glass bottles. The mixture stored in a 4°C freezer overnight, then filtered using Whatman no.1 paper. The filtrate was analyzed for its anthocyanin content by the method of (Francis, 1982). 1 ml of the extracted filtrate was diluted to 5 ml with 95% ethanol: HCl 1.5 N (85:15). Its absorbance was measured using a spectrophotometer at a wavelength of 535 nm. The following formula calculated total anthocyanin.

$$anthocyanin\left(\frac{mg}{100g\ material}\right) = \frac{(Absorbance\ x\ dilution\ factor)x100}{98{,}2\ x\ Sample\ Weight} \quad \text{……………..(1)}$$

The value of 98.2 is the molar absorption of anthocyanin pigments in etanol 95% and HCl 1.5 N (85:15) solution.

Ascorbic Acid (Suntornsuk, *et al.*, 2002) *with modification.*

A total of ± 5 grams of sample (fresh/powder) was put in a 50 ml flask and added with distilled water. The mixture was homogenized and filtered with Whatman No.1 filter paper. The iodine solution 0.01 N was prepared by mixing 2 grams of KI and 1,269 grams of I2. The mixture was dissolved with 1 liter of distillate water overnight to dissolve the iodine. The sample filtrate was added with 0.4 ml of a 1% soluble starch solution, titrated with 0.01 N iodine. The color change of the solution marks the titration endpoint into a blue tinge. 1 ml of 0.01 N iodine is equal to 0.88 mg ascorbic acid.

Capsaicin (Koleva-Gudeva, *et al.*, 2013)

The analysis of capsaicin content was performed with the following steps: 0.2 g of sample was dissolved in 25 ml of 95% ethanol. The maceration process is carried out in a volumetric flask for 5 hours using an orbital shaker with 200 rpm at room temperature. The extraction was carried out with Whatmann filter paper n.1. The absorbance of the filtrate was read at a wavelength of 280 nm. The value of the capsaicin is calculated based on the following standard curve equation:

$$\boldsymbol{Y = 9.484x + 0.016} \text{ ………………..(2)}$$

Where Y = absorbance value in 280 nm wavelenght and x = capsaicin consentration (mg/ml)

Non Enzimatis Browning Index

Measurement of non-enzymatic browning index was done based on (LEE, CHUNG, KIM, & YAM, 1991) with slight modifications. The stages were as follows: red pepper powder (0.1 ± 0.001 g) was dissolved in 50 ml of distilled water. The water-soluble pigment was extracted for 2 hours by axial shaker at 25 ºC and 140 rpm. It was then centrifuged at 4000 rpm for 16 min. The supernatant was filtered with a paper Whatman no 1 (pore size 0.45 mm) to remove suspended particles. The absorbance of the filtrate was measured at a wavelength of 420 nm using a spectrophotometer (Shimadzu UV 160U, Kyoto, Japan). The unit for Browning index value in this method is Abs / 0.1 gr sample).

Rehydration Ratio (Lewicki, 1998)

Approximately 2 g of dried sample was placed in a 100 ml beaker glass, and added by 50 ml distillate water. The glass was covered with aluminum foil. It is then heated to boil within 3 minutes and then cooled until 50 C. The rehydrated sample was drained using filter paper and weighed.

$$Rasio\ Rehidrasi = \frac{W_2}{W_1} \text{…………………(3)}$$

Where W1: weight of dried sample and W2: weight of rehydrated sample.

Carotenoid

The carotenoid analysis referred to (Etemadian, *et al.,* 2017) with slight modification. A total of 2.5 mg of dried chili powder was dissolved in 5 ml of 100% acetone then centrifuged at 5000 rpm for 10 min. Supernatant filtered with Whatman filter paper. The absorbance was read at 645, 663 and 470 nm wavelengths. The following equation obtained the content of carotenoid material (μg / ml)

$$Carotenoids\left(\frac{\mu g}{ml}\right) = \frac{(1000*A_{470})-(2.270*Ca)-(81.4*Cb)}{227} \text{……….….(4)}$$

Where Ca: Chlorophyl a, Cb: Chlorophyl b and A470: absorbance value in 470 nm wavelenght.

Statistical Analysis

The data obtained from this research were analyzed using ANOVA. It was continued with 5% BNT test if there was a significant influence to know the difference level among the treatments.

RESULTS AND DISCUSSION

Table 1. shows The average value of the dried red pepper quality attributes. They are rehydration ratio, non-enzymatic browning index, anthocyanin and carotenoids content, ascorbic acid and capsaicin content. The rehydration ratio described the extent of the cellular injury triggered by the drying process (Zielinska & Markowski, 2016). The non-enzymatic browning index, the content of anthocyanins and carotenoids affect the coloration quality of the dried product. The nutritional quality of the dried red pepper in this study was determined by the content of ascorbic acid and capsaicin. Ascorbic acid is one of the essential antioxidant compounds contained in red pepper. The value of ascorbic acid is affected by the drying method (Vega-Gálvez *et al.*, 2009). (Montoya-Ballesteros *et al.*, 2014) stated that carotenoids are bioactive compounds that influence the color quality of dried red pepper. The oxidation process of the carotenoid groups in the drying process has a potential to reduce the quality of the dried red pepper.

Table 1. Rates of Quality Atributes of Dried Red Pepper Resulted From Various temperature and layer Position of Convective Fixed Bed Drying

Treatments		Rehydration Ratio	Non-enzymatic browning index (Abs/0.1 mg)	Ascorbic Acid (mg/100g)	Capsaicin (mg/ml)	Athocyanin (mg/100 g)	Carotenoids (µg/g)
Drying System	Layer Position						
OSD		5.005	0.111762	43.9	0.066533	0.111762	0.886312
CCD 50 C	1st layer	4.535	0.2545	83.60	0.030841	0.193483	6.661662
	2nd layer	6.117	0.2533	74.80	0.016607	0.198574	5.453861
	3rd layer	5.533	0.2663	87.00	0.015553	0.156823	6.078326
	4th layer	6.517	0.1690	88.00	0.014762	0.121181	3.785992
	5th layer	5.893	0.2055	87.00	0.014235	0.300407	4.177713
CCD 60 C	1st layer	4.283	0.1285	67.80	0.071858	0.166242	13.54959
	2nd layer	4.663	0.1045	54.60	0.071489	0.101324	11.73727
	3rd layer	4.578	0.1160	54.60	0.069380	0.140020	11.43471
	4th layer	4.398	0.0820	67.80	0.073202	0.113544	12.09916
	5th layer	4.883	0.0740	54.60	0.063923	0.079684	10.49436
CCD 70 C	1st layer	4.338	0.2408	70.40	0.051613	0.130601	10.42133
	2nd layer	4.110	0.2428	57.20	0.052140	0.120672	9.795473
	3rd layer	4.345	0.1940	78.00	0.063133	0.097760	6.599396
	4th layer	4.455	0.1353	66.00	0.065452	0.099796	6.800756
	5th layer	4.165	0.1238	70.40	0.069670	0.075611	5.261851
CSD	1st layer	5.748	0.1638	60.80	0.057913	0.165733	5.488438
	2nd layer	4.900	0.1486	74.60	0.070672	0.177189	3.848599
	3rd layer	5.461	0.1243	51.40	0.056464	0.121181	4.906312
	4th layer	5.688	0.1071	47.00	0.052272	0.112525	2.462062
	5th layer	5.990	0.1713	35.10	0.061340	0.097760	5.368753
Treatments VS OSD (Control)		Sig	NS	NS	NS	NS	NS
Drying system vs Layer positions		NS	NS	sig	NS	NS	NS
Drying system		sig	sig	sig	sig	NS	sig
Layer positions		NS	NS	NS	NS	NS	NS

Rehydration ratio

The value of rehydration ratios as a result of several drying systems in various layer positions was ranging from 4.28 to 6.52. There was a significant different between CCD and CSD compared to OSD. There was no interaction between the drying system and the layer position at the rehydration ratio (Table 1). Separately, the drying system significantly affected the rehydration ratio (Figure 1). Rehydration ratio illustrated the degree of cell structure injury of the dry matter. The result of this study showed that the convective drying of red pepper using CCD 50°C and CSD gave better values of rehydration ratio than the dried red pepper from the convective drying at 70°C. That phenomenon might be occurred due to the structure and cellular injury triggered by the temperature, which reduced the intercellular capability to absorb water. The result of this research coincided with the study of (Veras *et al.*, 2012).

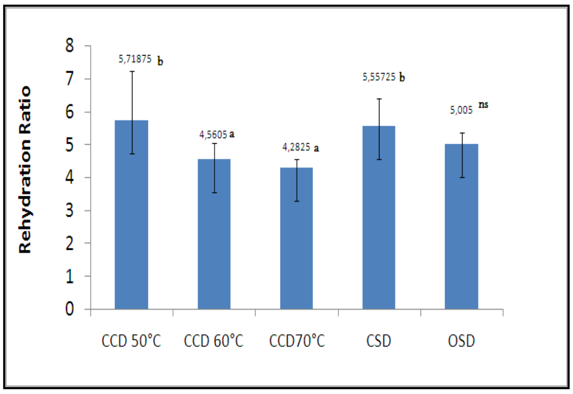

Figure 1. The effect of drying system on the Rehydration Ratio of Dried red pepper

Non-Enzimatic Browning Index

The change of color is an essential variable that needs to be prevented in red pepper drying. One of the variables determines the color change in a drying process is non-enzymatic browning index. The analysis of variance (5%) confirmed a significant effect of the drying system on the value of non-enzymatic browning index. Figure 2 shows that the browning index of CCD 50°C is the highest followed by CCD 70°C, CSD, OSD, and CCD 60°C. It supposed to be happened because the red pepper dried in CCD 50°C has the most extended heat exposure (50 hours) compared with the other drying system. Meanwhile, the CSD had the lowest drying temperature rates (44-57°C) and higher velocity compared with the CCD. The greater non-enzymatic browning index values indicate a lower quality of the dried products. (Maillard, 1912), who studied the influence of temperature and length of heating time on the reaction rates, explained that along the drying process, the increasing temperature or drying time would increase the reactivity of sugars and Amino groups. It is known as Maillard reaction. (Hodge, 1953) stated that the pathway of Maillard reaction might change with the different drying conditions. Figure 2 shows that the CCD 60°C is the best combination of temperature and drying time (32 hours) to gain dried red peppers with low non-enzymatic browning index. The similar conclusion were also noted by (Jokić *et al.*, 2009), (Deng *et al.*, 2018), and (Wang *et al.*, 2017).

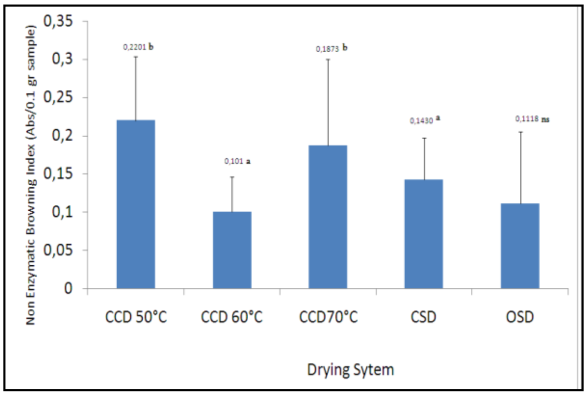

Figure 2. The effect of drying system on non-enzymatic browning index

Ascorbic Acid

The drying system had significant effect on the ascorbic acid content. It ranged between 35.1-83 mg/100 g of materials. The ascorbic acid content of the dried red pepper from CCD 50°C is significantly higher than that from the CCD 60°C and CCD 70°C (Figure 3). It supposed to be caused by an irreversible oxidation process (Veras, *et al.*, 2012). (Zielinska & Markowski, 2016) and (Deng, *et al.*, 2018) stated that the decrease in ascorbic acid depended on the temperature and drying period. Dried red pepper from CSD and OSD tended to have lower ascorbic acid compared with the CCD in various temperature. (Toontom, *et al.*, 2012) stated that Ascorbic acid was easily oxidized by the light and temperature during a drying process and formed L-dehydroascoebic acid. The result of this study is such a little bit higher than the result of ascorbic content of dried red pepper using some drying methods by (Toontom, *et al.*, 2012).

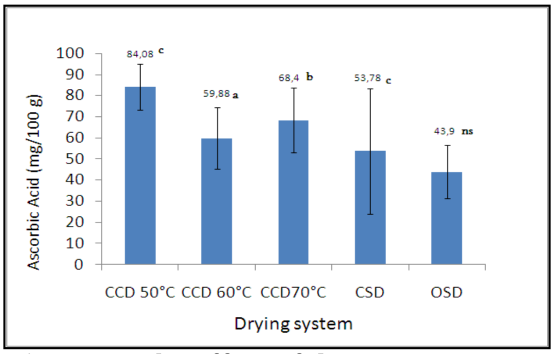

Figure 3. The effect of drying system on Ascorbic Acid

Capsaicin

It was found that the drying system significantly influenced the capsaicin content of dried red peppers. Figure 4 shows that the capsaicin content of dried red pepper from CCD 60°C is the highest which is not statistically different with the capsaicin content of dried red pepper from CCD 70°C, CSD and OSD. The dried red pepper from CCD 50°C had the lowest capsaicin content. The result is similar to the study of (Toontom, *et al.*, 2012)), who explained that the level of capsaicin extractability would rise alongside with the extent of drying time and drying temperature. The possible explanation for that kind of phenomena is the process of glycosides hydrolisis. According to (Díaz, *et al.*, 2004) red peppers consist of free capsaicin and bounded capsaicin with sugars and other compounds. Drying process will destroy the glycosides linkage of the bounded capsaicin, so the content of capsaicin in dried red pepper will increase.

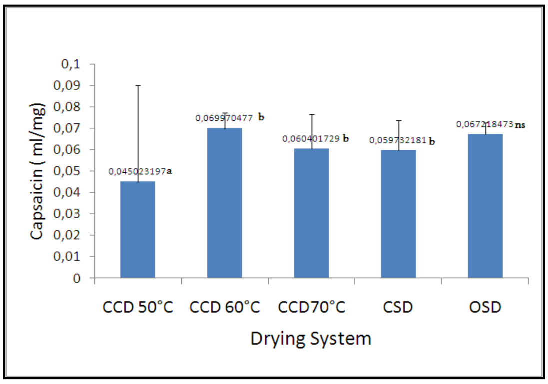

Figure 4. The Effect of Drying System on Capsaicin of Dried Red Pepper

Anthosianin and Carotenoids

The result of the study showed that the drying system did not influence the anthocyanin content of dried red pepper, but it significantly influenced the carotenoids (Table 1). Figure 5 shows that CCD 60°C gave the best carotenoids content compared with the other treatments. The carotenoids of dried red pepper from CCD 50°C is similar to that from CSD. The dried red peppers from open sun drying had the lowest carotenoids.

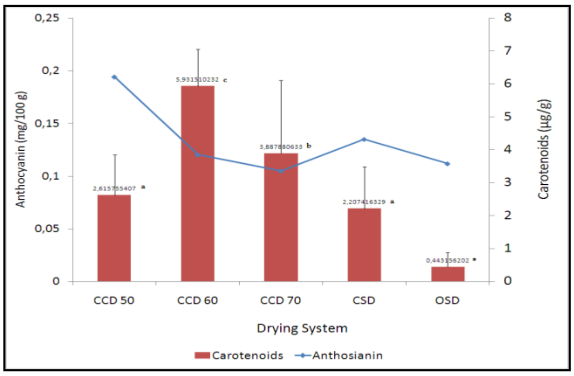

Figure 5. The effect of drying system on Anthocyanins and Carotenoids of the Dried Red Pepper

According to (Soria, *et al.*, 2009) the degradation of carotenoids in a drying process was not only triggered by chemical factors but also by the structural damage that occurs in a drying process. (Jokić, *et al.*, 2009) and (Vega-Gálvez, *et al.*, 2012) stated that the color quality of dried products is directly associated with their carotenoids content. (Mulokozi & Svanberg, 2003) stated that the carotene content of dried green leafy vegetables with solar dryers are higher than that from open sun drying. Meanwhile, the value of beta-carotene of dried products using oven is higher than the beta-carotene content of the dried sample from open sun drying. The result of this research is also in line with the results of (Díaz *et al.*, 2004) and (Navale, *et al.*, 2015)

CONCLUSION

This study presents attribute quality analysis on dried red pepper resulted from CCD,CSD, and OSD drying system. Some important quality attributes, *i.e.*, color quality (represented by non-enzymatic browning index, anthocyanin, and carotenoids), nutrition quality (ascorbic acid and capsaicin), and cellular injury (represented by rehydration ratio) were observed thoroughly. The result of the study confirmed that the drying system statistically affected all the observed quality attributes of dried red peppers. The CCD 50°C and CSD resulted in dried red pepper with the best rehydration ratio. The CCD 60°C gave the best capsaicin, carotenoids and non-enzymatic browning index. The CSD gave a satisfactory result on non-enzymatic browning index and capsaicin. The values were not significantly different with the dried red pepper from CCD 60°C. The value of carotenoids, rehydration ratio, and ascorbic acid of dried red pepper gained from CSD was not significantly different with those quality attributes of CCD 50°C. Overall, the result of the study showed that convective solar drying based on a solar collector and photovoltaic produced dried red pepper with satisfactory quality.

SUGGESTION

Based on the result of the study, the researchers suggest the using of the convective solar drying based on a solar collector and photovoltaic to produce high quality of dried red pepper. The dryer is an eco-friendly, easy to apply, convenient and assessable for the farmers in rural areas.

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