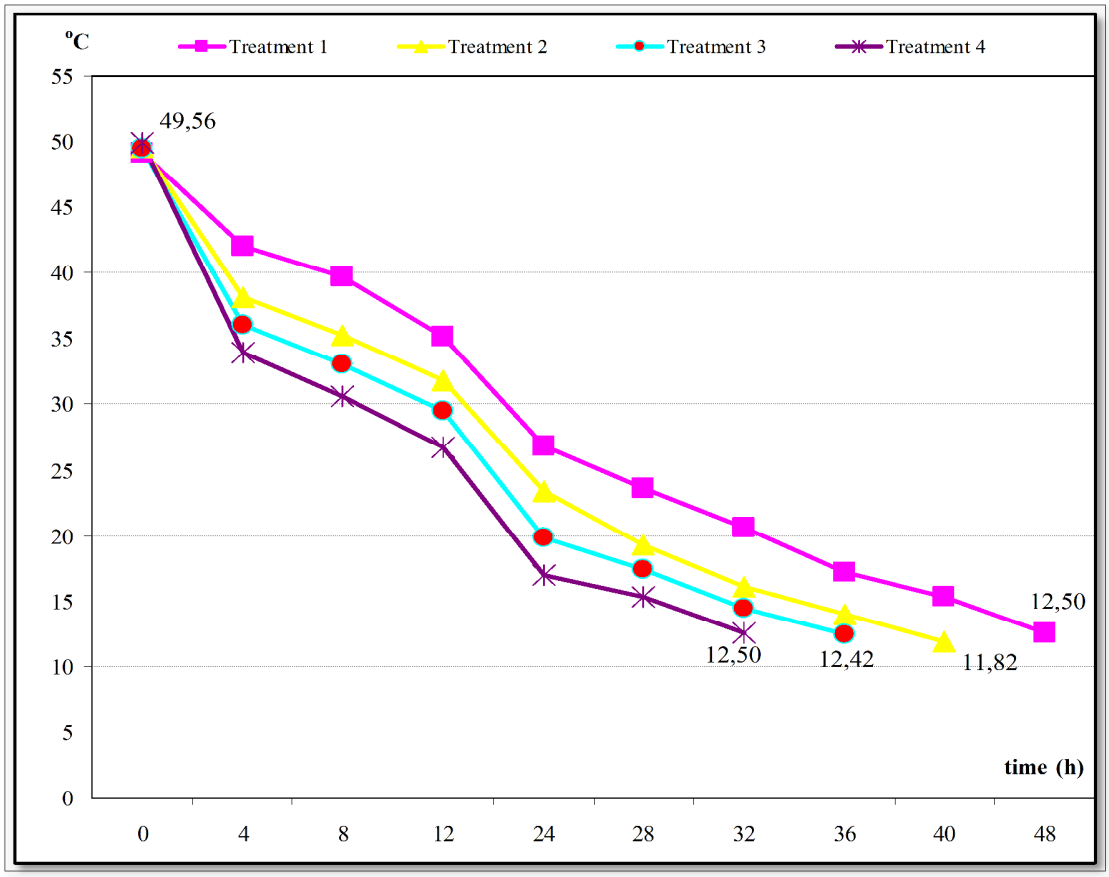

Figure 1. Peppercorn moisture during drying (%wb).

Results on determining the quality of final products

During the drying process, the color of the pepper will be changed according to drying temperatures and drying times **(Table 2)**.

Table 2. Changes of the peppercorn colors during drying.

Peppercorn colors before drying	Peppercorn colors after drying
Dark red	Dark red, black
Light red	Dark red, light red, black
Yellow	Dark red, light red, yellow, black
Green	Green, black
Black	Black

Red pepper in the treatments was dried at different temperatures, the drying time of the products was different. As the result, the products would be different in peppercorn color ratio **(Table 3)**.

From the results, the color of final product in each treatment had significant different comparing to the control (natural drying). For treatments using heat-pump drying, the percentage of gains that were changed in color during drying was lower than that for control sample, especially for red and yellow beans. The percentage of the black beans in treatments (27.2 - 32.2%) was statistically significantly lower than that of the control samples (63.2%). The heat pump drying system proves to be able to keep the light red color of pepper quite well, between 27.3% and 33.2% in which, the lower temperature gave the higher ratio of pepper with light red color. However, the high temperature from 35^0C to 40^0C contributed to reduce the ratio of these pepper significantly. Thus, it should be set the drying temperature under 35^0C in order to gain products with high ratio of red beans and low ratio of black beans. The result of evaluation of pepperine content (4.74 - 4.8%) and volatile oil content (2.18 - 2.26 ml/100g of dry matter) shows that there was not any difference between the drying treatments; and there was not much differences comparing with the control samples. These results correspond to the results of Srinivasan [5-7]. The product after drying has the spicy flavor which is characteristic aroma of pepper.

Table 3. Quality of pepper products after drying.

Treatment	Peppercorn color (%)					Piperine (%)	Volatile oils (ml/100g)	Flavor of product
	Dark red	Light red	Yellow	Green	Black			
T1	19.2	32.3 a	15.1	5.5	27.9 c	4.74a	2.23a	Spicy flavor, characteristic aroma
T2	21.6	32.1 a	14.5	4.6	27.2 c	4.76a	2.19a	Spicy flavor, characteristic aroma
T3	23.9	33.2 a	12.2	3.3	27.4 c	4.79a	2.26a	Spicy flavor, characteristic aroma
T4	26.3	27.3 b	11.4	2.8	32.2 b	4.75a	2.18a	Spicy flavor, characteristic aroma
Natural drying	28.3	8.5 c	0	0	63.2 a	4.73a	2.06a	Spicy flavor, characteristic aroma

Determination of method for processing raw materials before drying to improve the quality of products

Results of determination of raw material quality

The purpose of processing raw materials before drying is to inactivate the enzyme inside the beans in order to reduce the color change of the pepper happening during drying.

The results **(Table 4)** show that after processing, there was slightly difference in the color of pepper between these treatments and raw material. Treatment 3, which used, cold water to treat raw material, did not affect the color of pepper. Thus, the color of pepper was the same as the color of raw material. In treatment using hot water, the raw materials after processing have been changed in color from yellow to light red and from light red to dark red. Dark red beans ratio have increased about 5% compared to the raw material (from 18.6% to 20.4%). In treatment processing raw material with microwave, there was a quick change in color, especially from light red to dark red. Dark red beans ratio have increased about 8% compared to the raw material (from 18.6% to 21.5%).

Table 4. Quality of raw material after processing.

Treatment	Quality of raw material after processing (%)				
	Dark red	Light red	Yellow	Green	Black
T1	20.4	37.4	29.5	8.5	4.2
T2	21.5	34.0	31.8	8.5	4.2
T3	18.6	36.4	32.3	8.5	4.2
Raw material (untreated)	18.6	36.4	32.3	8.5	4.2

Results of determination peppercorn moisture during drying

The results **(Figure 2)** show that when the raw materials processed by cold water and hot water, the moisture content of the material increased. However, in the treatment processed by hot water, the moisture of the material reduced quickly after 4 h and had equal amount to the control while in the treatment processed by microwave, the moisture

content of the raw materials reduced quickly from the begin of drying step and was always at the lowest level during drying compared to other treatments. In contrast, the moisture content of pepper in the treatment processed with cold water increased quickly from the begin of drying and was always at the highest level compared to other treatments during drying. The treatment processed by microwave gave product with the required moisture (12-13%) after 32 h of drying. It took 36 h for treatments processed by hot water and control to gain desired moisture while the treatment using cold water was not able to achieve required moisture after 36 h of drying.

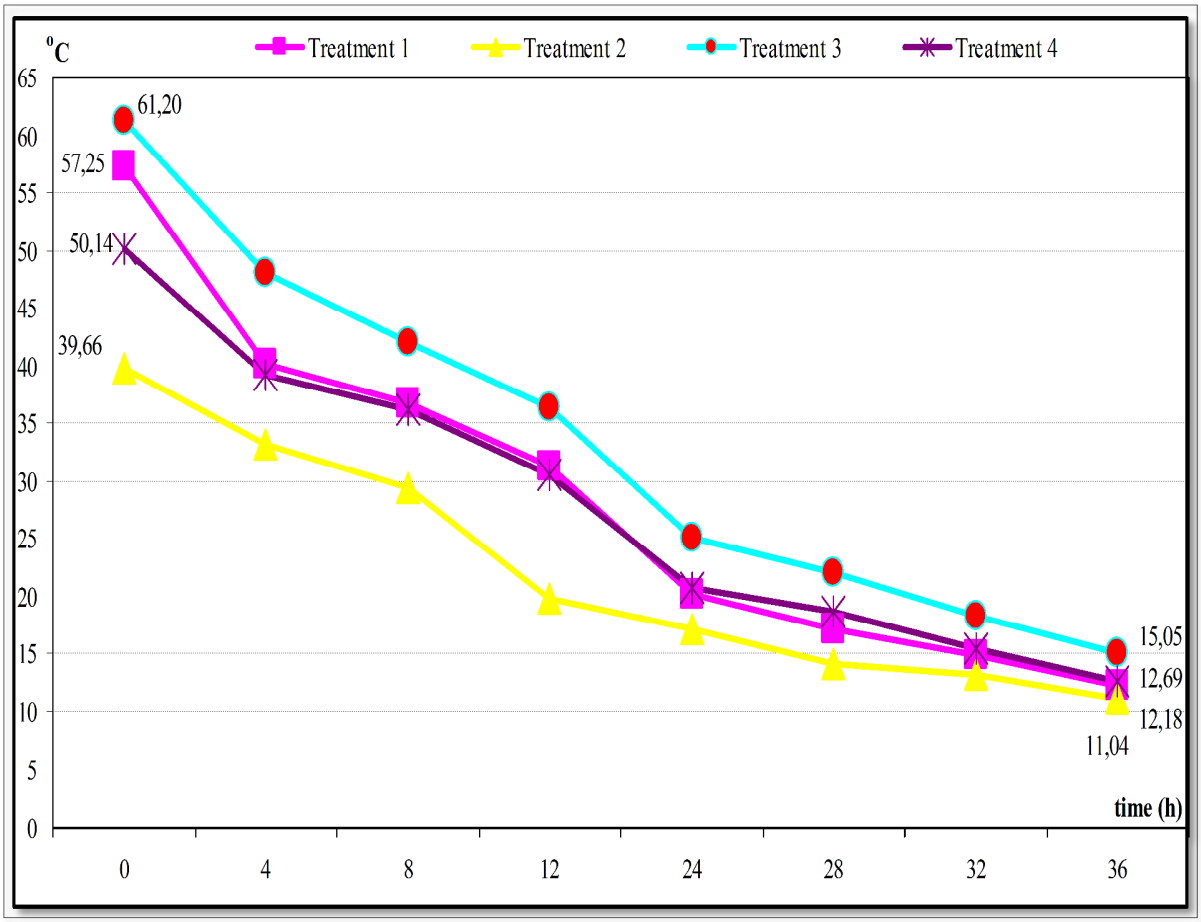

Figure 2. Peppercorn moisture during drying (%wb).

Results of determination quality final product

The results **(Table 5)** show that the color of the peppercorn beans between the treatments was significant difference. The treatments processed by hot water and microwave made the color of peppercorns very nice (the light red beans were higher) and reduced the ratio of the black beans. It was probably because processing by hot water and microwave was able to inactivate enzyme, which contribute to the maintenance of the color of product better and not making the color of raw materials to be changed too much during drying. The peppercorn color of the treatment processed with cold water were not significantly different compared to the control. In order to use microwave for treating raw material in large quantities, it is necessary to invest in high-value equipment with high safety level for workers. Therefore, it is recommended that hot water should be used in processing raw material before drying in order to decrease investment cost.

The results of the evaluation of pepper content, volatile oil content and product quality show that there was not difference between the treatments. The content of pepperine (4.76 - 4.81%), volatile oil content (2.14 - 2.20 ml/100g dry matter) is correspond to the results of Saha [6] and Morshed [7]. The product of all treatments had a spicy flavor which is the characteristic aroma of pepper. The treatment processed by hot water produced cleaner product compared to other treatments.

Table 5. Quality of pepper product after drying.

Treatment	Peppercorn color (%)					Piperine (%)	Volatile oils (ml/100g)	Flavor of product
	Dark red	Light red	Yellow	Green	Black			
T1	17.4	39.8a	13.2	2.3	27.3ab	4.80a	2.19a	Spicy flavor, clean and characteristic aroma
T2	16.6	35.5ab	18.5	4.2	25.2 b	4.76a	2.14a	Spicy flavor, characteristic aroma
T3	18.3	31.8b	14.2	4.3	31.4a	4.81a	2.20a	Spicy flavor, characteristic aroma
T4	18.7	32.5b	14.6	4.6	29.6ab	4.78a	2.16a	Spicy flavor, characteristic aroma

CONCLUSION AND RECOMMENDATION

- The heat pump drying mode suitable for red pepper production was: drying temperature at 35^{0}C, air humidity 40%, wind speed of 3m/s and drying time in 36 h. the moisture content of products was less than 13%, black pepper ratio was 27.5%, color and sensory quality of products were very good
- The treatment of raw materials with hot water at 90^{0}C in 1 min was able to increase product quality and keep the color of product better and shorten drying time **(Figure 3)**.

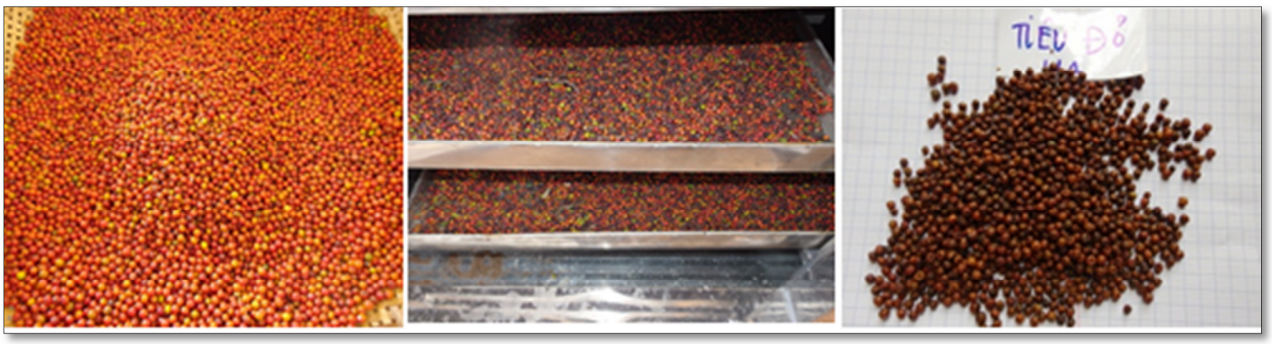

Figure 3. Peppercorn before, during and after drying by heat pump drying.

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