

3. RESULTS

3.1. Temperature Profile

Profile of temperature during drying process in Solar Tunnel Dryer (STD) can be seen in Figure 5.

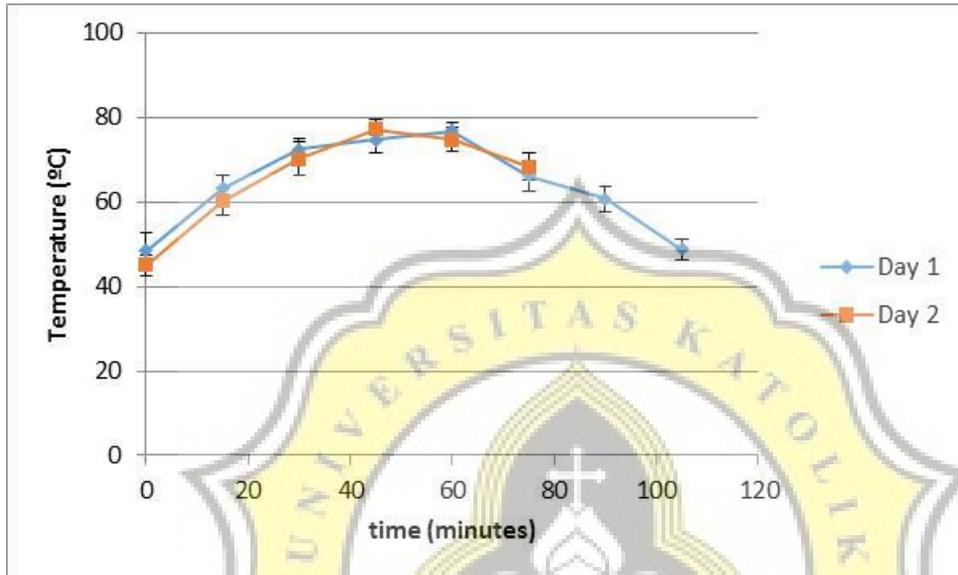


Figure 5. Temperature profile during drying process

Based on Figure 5., we can see the drying process in 2 days. In the first day, the temperature inside the Solar Tunnel Dryer reached the maximum temperature in the 60th minutes. In the second day, the maximum temperature can be reached faster than the first day, i.e. 45th minutes.

3.2. Water Content

The water content of the drying process of curcuma in Solar Tunnel Dryer every 15 minutes can be seen in Table 1.

Table 1. The Water Content Every 15 Minutes

Day	Time	C0	C1A	C1B	C1C	C2A	C2B	C2C	C3A	C3B	C3C
1 st	t-0	73.31±4.74	76.37±4.76	77.89±1.78	78.66±4.43	78.72±1.44	81.27±1.38	82.36±2.08	74.19±4.53	78.95±0.08	81.73±2.68
	t-15	53.19±7.15	55.46±3.39	59.86±3.50	55.78±7.90	61.97±0.42	58.52±3.45	70.99±1.19	59.90±0.68	65.83±5.55	65.89±3.17
	t-30	32.64±8.39	33.40±2.78	43.69±8.76	37.46±13.04	47.39±3.12	53.80±12.14	59.59±3.05	43.16±2.20	37.17±1.51	48.99±0.06
	t-45	22.18±5.35	21.58±0.72	32.87±7.17	26.06±10.63	36.44±3.04	32.06±1.54	48.36±4.08	33.65±2.61	36.09±5.21	34.94±0.50
	t-60	15.67±1.72	14.36±0.07	24.52±7.02	18.01±7.18	27.95±0.00	21.59±2.24	38.34±4.87	22.88±0.41	16.78±0.73	15.15±0.48
	t-75	12.56±0.41	12.38±1.46	17.61±4.11	14.10±3.81	21.63±0.01	16.29±1.58	23.17±1.90	16.34±1.60	11.34±0.09	10.98±0.53
	t-90	9.45±0.90	9.50±1.71	11.17±1.57	7.89±2.13	13.53±5.74	9.77±0.33	17.73±0.14	11.87±1.14	9.78±0.02	8.37±1.30
2 nd	t-105	8.51±0.99	8.05±1.84	9.70±1.60	8.11±1.05	11.47±3.58	8.98±0.04	12.67±2.21	9.55±1.12	7.83±0.79	8.33±0.10
	t-120	8.55±0.33	8.08±1.16	8.47±1.97	7.34±0.03	7.29±0.10	7.41±0.78	8.64±0.63	8.18±1.13	7.58±0.52	5.00±0.24
	t-135	7.82±0.73	7.60±1.20	7.24±1.64	6.31±0.01	6.24±0.09	5.26±0.71	5.26±0.41	5.21±0.20	6.68±0.14	4.48±0.49
	t-150	7.36±0.15	6.33±0.45	5.90±0.79	5.62±0.36	5.82±0.07	4.77±0.75	-	4.24±0.13	5.40±0.17	-
	t-165	7.01±0.01	5.97±0.25	4.83±0.93	-	-	-	-	-	-	-
	t-180	6.46±0.05	-	-	-	-	-	-	-	-	-

Description:

1. All values are average ± standard deviation

2. Treatment C0 = control; C1A = 0.5% citric acid soaking 10'; C1B = 0.5% citric acid soaking 20'; C1C = 0.5% citric acid soaking 30'; C2A = 1% citric acid soaking 10'; C2B = 1% citric acid soaking 20'; C2C = 1% citric acid soaking 30'; C3A = steam blanching 3'; C3B = steam blanching 5'; C3C = steam blanching 10'

Based on Table 1., we can see water content of curcuma every 15 minutes when the drying process in Solar Tunnel Dryer (STD). Curcuma control (C0) required 180 minutes to reach water content <7%, whereas curcuma soaked in citric acid required 150 until 160 minutes to reach water content <7%. Curcuma steam blanched required 135-150 minutes to reach water content <7%. The fastest curcuma to reached water content <7% is curcuma soaked in 1% citric acid solution for 30 minutes and steam blanched for 10 minutes.

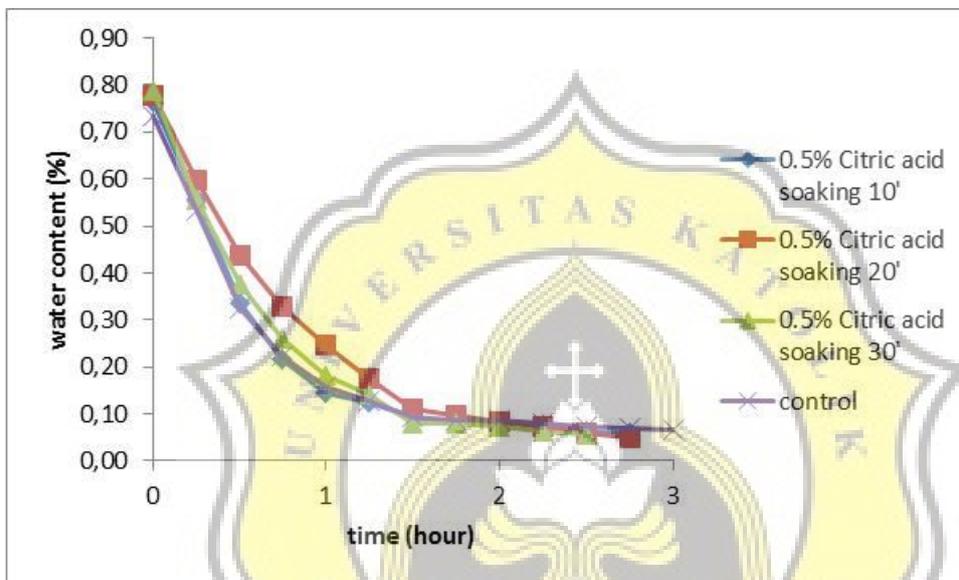


Figure 6. Water content of curcuma control and soaked in 0.5% citric acid

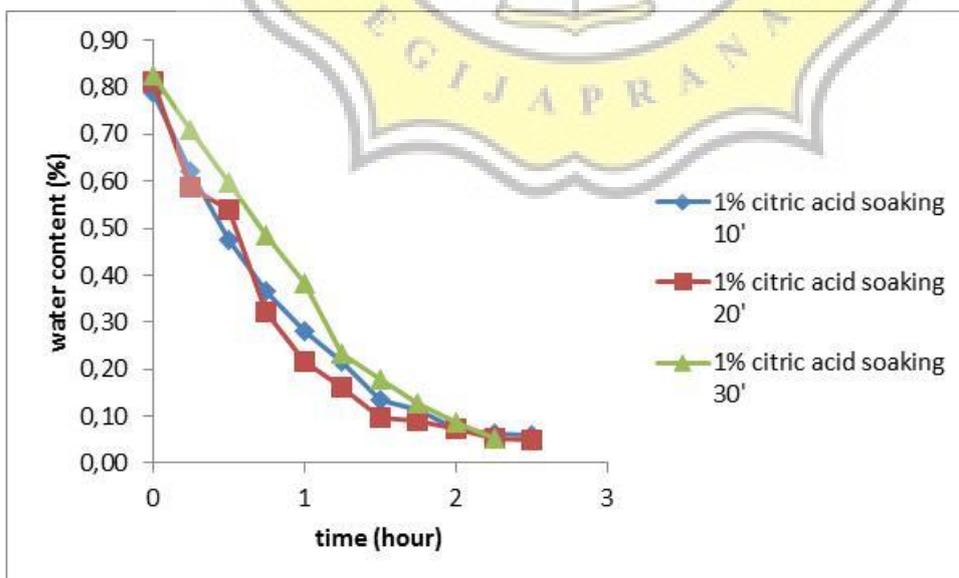


Figure 7. Water content of curcuma soaked in 1% citric acid

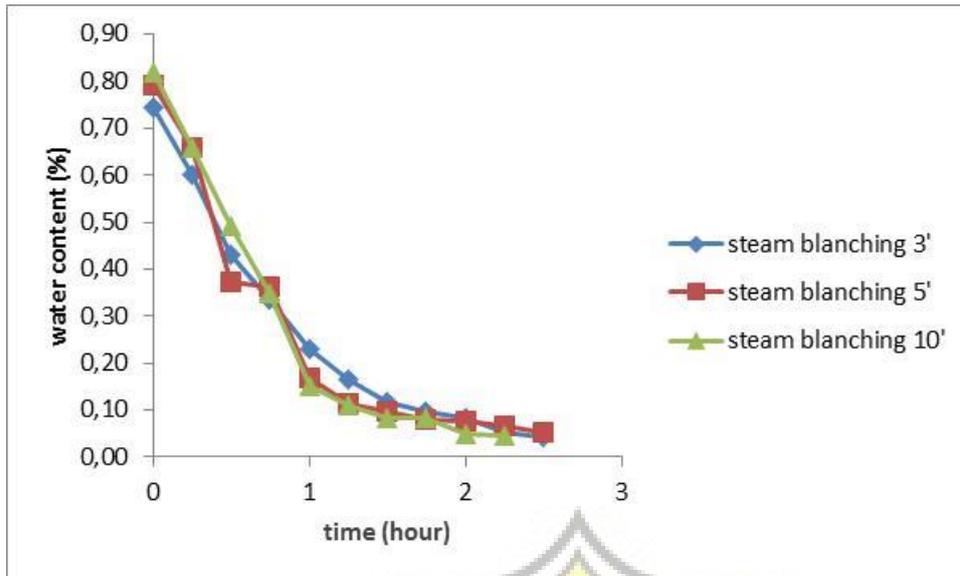


Figure 8. Water content of curcuma steam blanched

Figure 6 until Figure 8. showed the decreasing of water content during the drying process. Based on Figure 6., curcuma control and soaked in 0.5% citric acid for 10 minutes had similar diagram about the decreasing of water content, but curcuma control needed more time to dried. After a half and hour, the decrease of water content were insignificant. Figure 7. showed that the fastest to dried was curcuma soaked in 1% citric acid solution for 30 minutes, but the deacresing of water content in the initial was longer than curcuma soaked in 1% citric acid solution for 10 and 20 minutes. After a half and hour, the decrease of water content were insignificant. Based on Figure 8., on the first hour, the water content significantly decreased. After first hour, the decreasing of water content became insignificant.

3.3. Antioxidant Activities (% Inhibition)

The result of antioxidant activities (% inhibition) of curcuma before and after drying process in dry basis can be seen in Table 2.

Table 2. The Antioxidant Activities (% Inhibition) of Curcuma Before and After Drying Process

Treatment	% Inhibition	
	Before Drying	After Drying
C0	91.74 ± 2.25 ^{de,NS}	89.31 ± 1.67 ^{ab,NS}
C1A	70.43 ± 8.92 ^{a,S}	91.13 ± 0.34 ^{b,S}
C1B	89.70 ± 4.60 ^{cde,NS}	90.76 ± 2.14 ^{b,NS}
C1C	92.74 ± 3.30 ^{e,NS}	90.98 ± 2.88 ^{b,NS}
C2A	82.13 ± 11.39 ^{bc,NS}	91.04 ± 1.49 ^{b,NS}
C2B	80.77 ± 10.62 ^{b,NS}	90.36 ± 0.77 ^{b,NS}
C2C	84.22 ± 1.35 ^{bcd,S}	89.22 ± 1.36 ^{ab,S}
C3A	93.49 ± 0.71 ^{e,NS}	93.28 ± 1.04 ^{c,NS}
C3B	86.91 ± 3.77 ^{bcd,NS}	87.91 ± 3.01 ^{a,NS}
C3C	87.35 ± 6.22 ^{bcd,NS}	87.80 ± 0.32 ^{a,NS}

Description:

1. All values are average ± standard deviation
2. Value with different superscript in each condition show significant differences in the confidence level of $\alpha = 0.05$, NS= Non-significant and S=Significant, the value between before and after drying.
3. Treatment C0 = control; C1A = soaking 0.5% citric acid 10'; C1B = soaking 0.5% citric acid 20'; C1C = soaking 0.5% citric acid 30'; C2A = soaking 1% citric acid 10'; C2B = soaking 1% citric acid 20'; C2C = soaking 1% citric acid 30'; C3A = steam blanching 3'; C3B = steam blanching 5'; C3C = steam blanching 10'

Based on Table 2., we can see the antioxidant activities (% inhibition) of curcuma before drying process almost higher than curcuma after drying process. The highest antioxidant activities (% inhibition) of curcuma before drying process is curcuma steam blanched for 3 minutes (C3A). After drying process, curcuma steam blanched for 3 minutes (C3A) gave the highest concentration of % inhibition with the value is 93.28±1.04%.

3.4. Curcumin Contents Using HPLC and Spectrophotometer

The separation of curcumin contents from curcuma before and after drying process with different pretreatments are presented in Figure 9 to Figure 11.

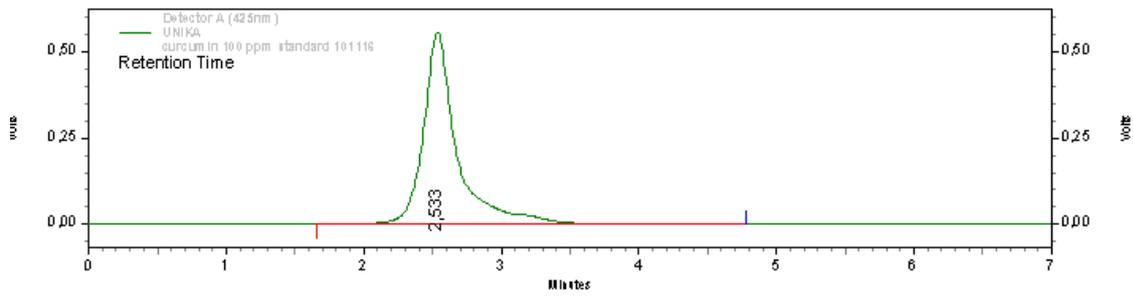
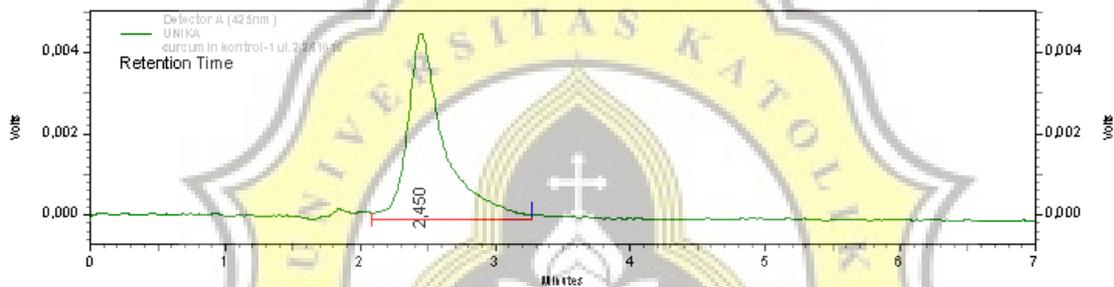
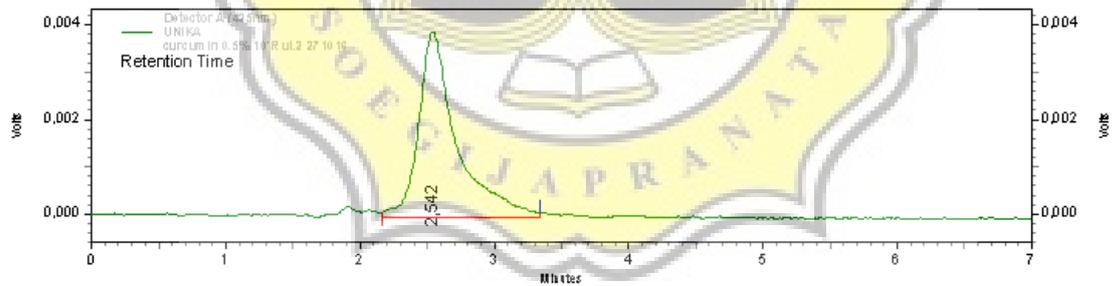


Figure 9. Chromatograms of curcumin standard

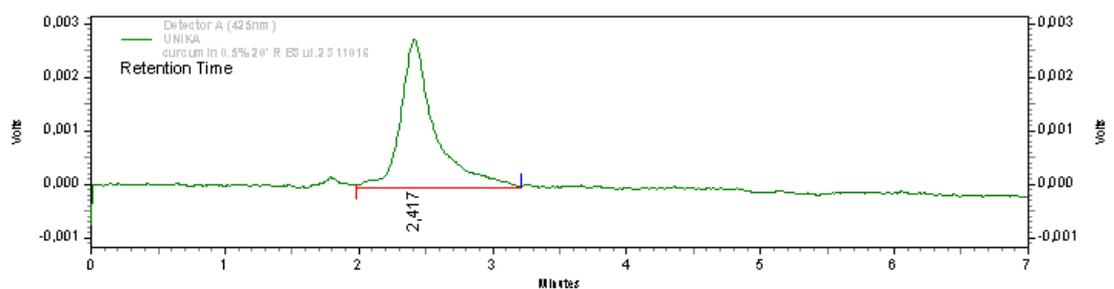
The separation of curcumin contents from curcuma before drying process control and pretreatments (citric acid soaking and steam blanching). The retention time and separation for curcumin content can be seen in Figure 10.



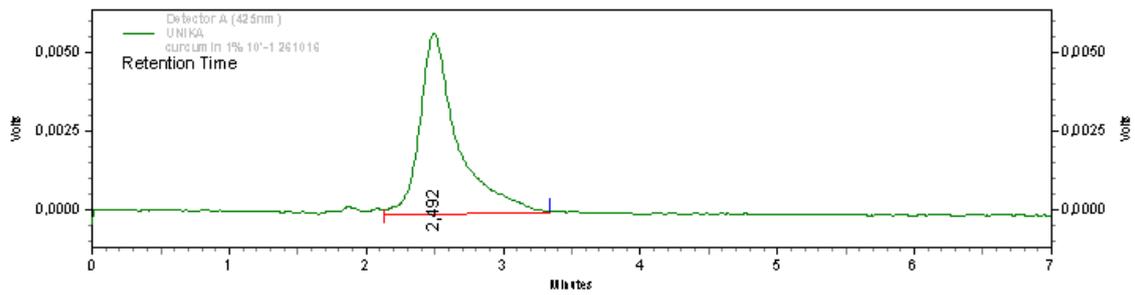
(a) Curcuma control



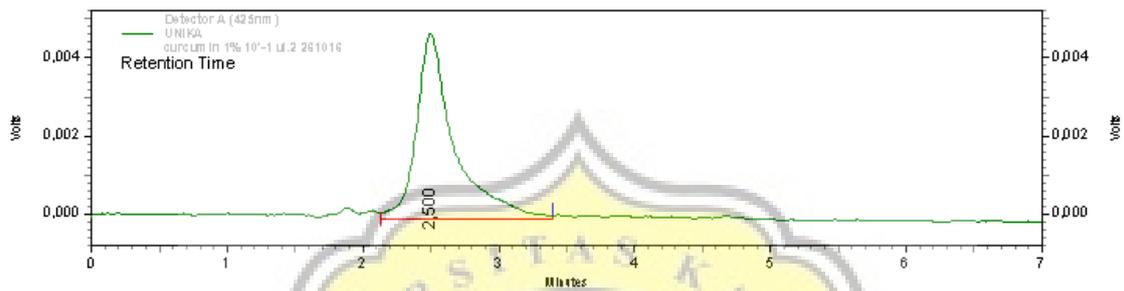
(b) Curcuma soaked in 0.5% citric acid solution for 10 minutes



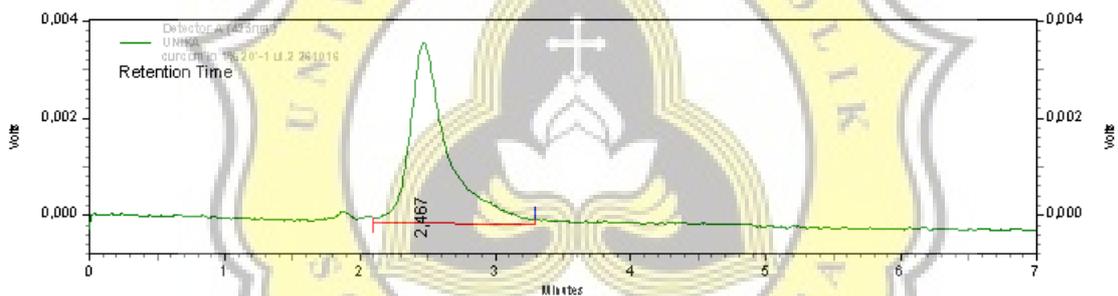
(c) Curcuma soaked in 0.5% citric acid solution for 20 minutes



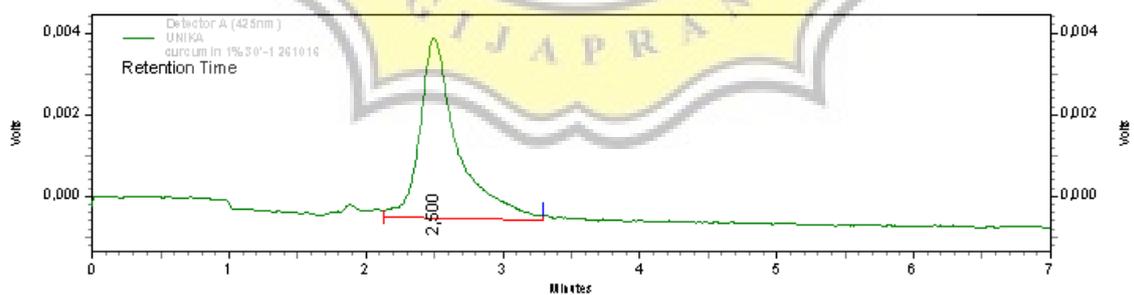
(d) Curcuma soaked in 0.5% citric acid solution for 30 minutes



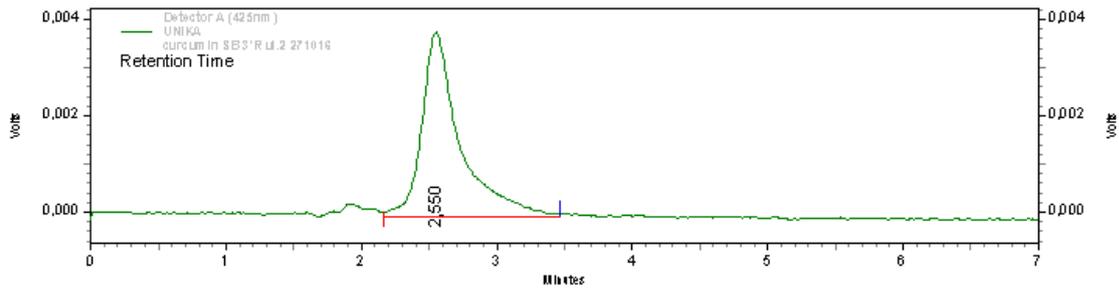
(e) Curcuma soaked in 1% citric acid solution for 10 minutes



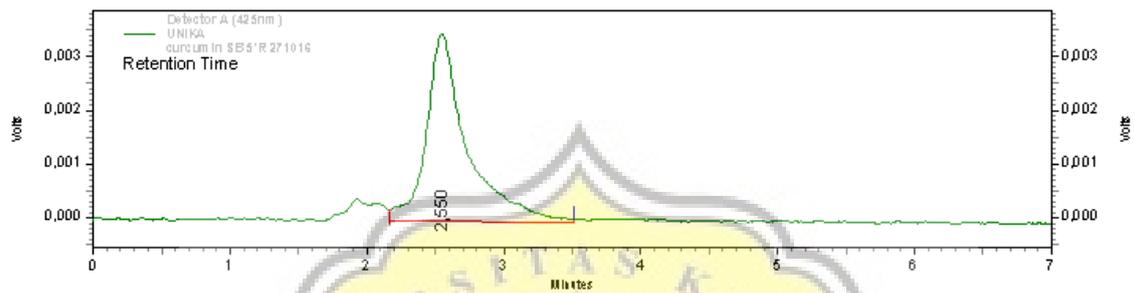
(f) Curcuma soaked in 1% citric acid solution for 20 minutes



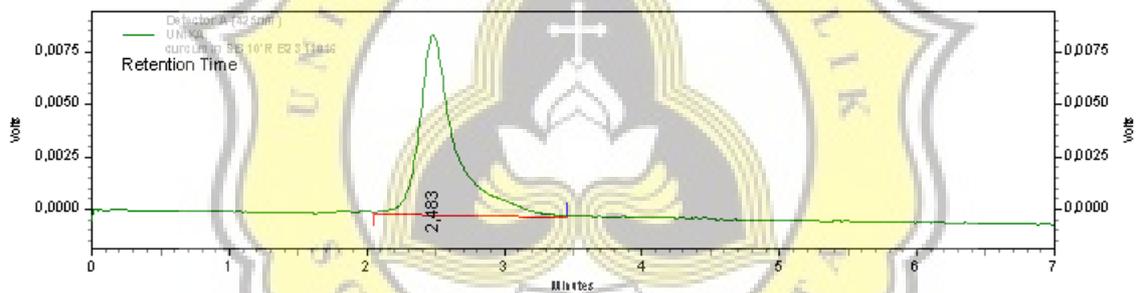
(g) Curcuma soaked in 1% citric acid solution for 30 minutes



(h) Curcuma steam blanched for 3 minutes



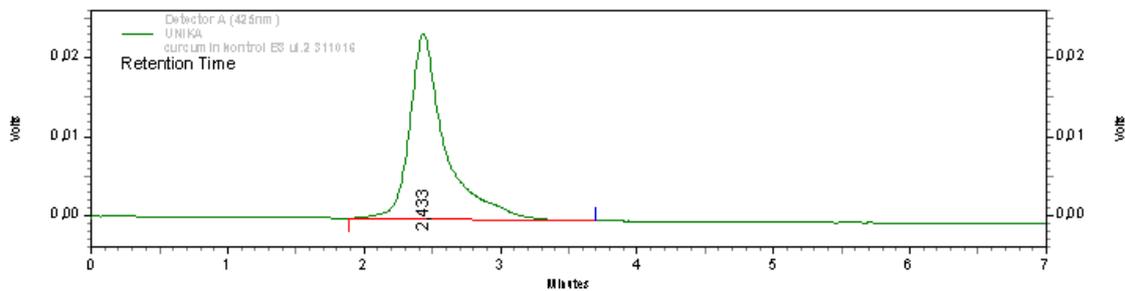
(i) Curcuma steam blanched for 5 minutes



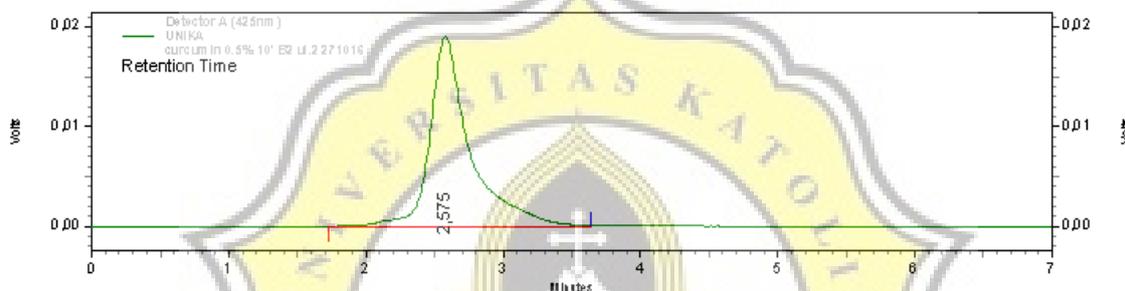
(j) Curcuma steam blanched for 10 minutes

Figure 10. Chromatograms of curcumin contents in curcuma before drying process

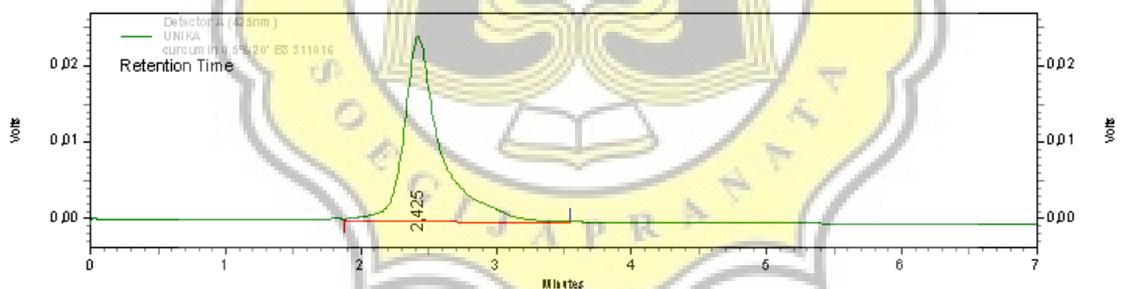
Curcumin contents' separation from curcuma after drying process had retention time between 2,433 to 2,575 . The results can be seen in Figure 11.



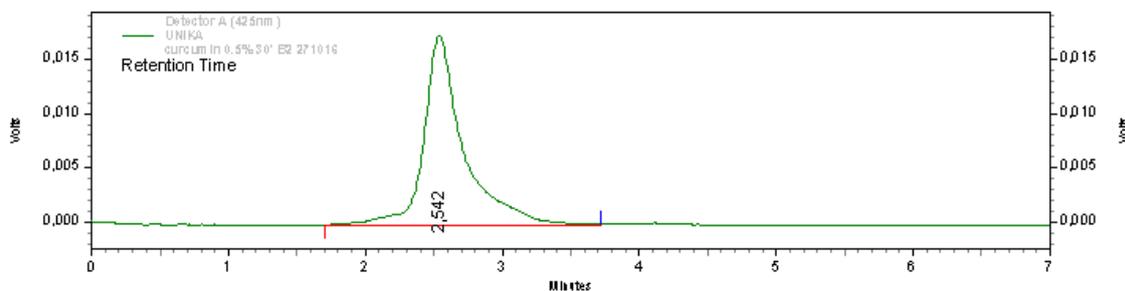
(a) Curcuma control



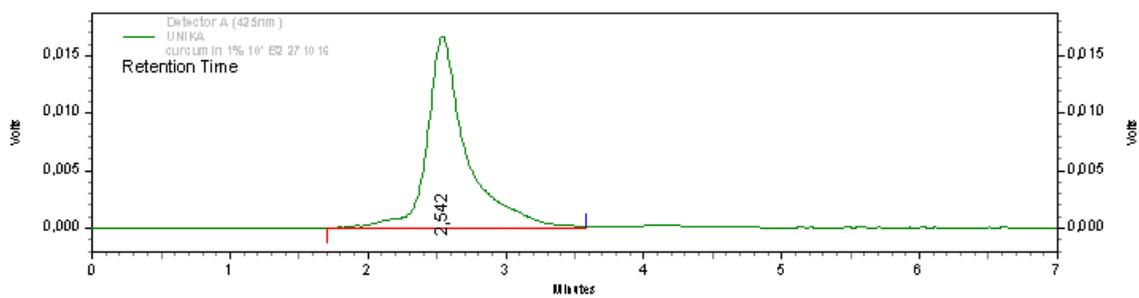
(b) Curcuma soaked 0.5% citric acid solution for 10 minutes



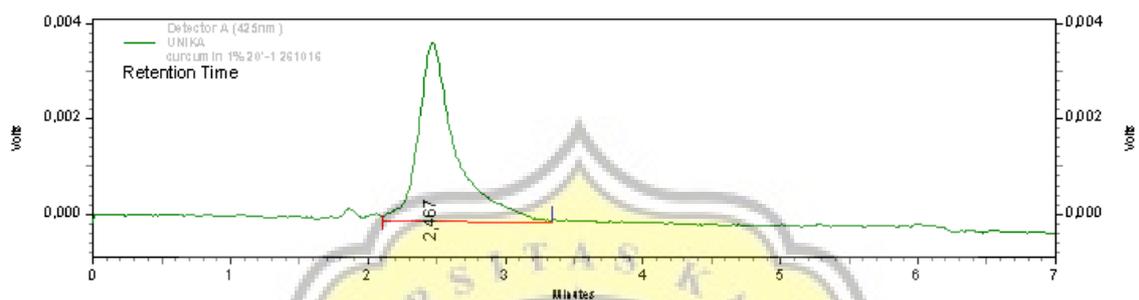
(c) Curcuma soaked 0.5% citric acid solution for 20 minutes



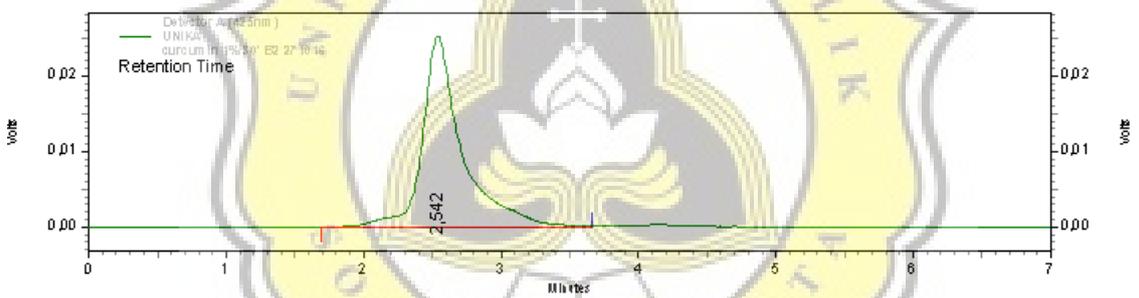
(d) Curcuma soaked 0.5% citric acid solution for 30 minutes



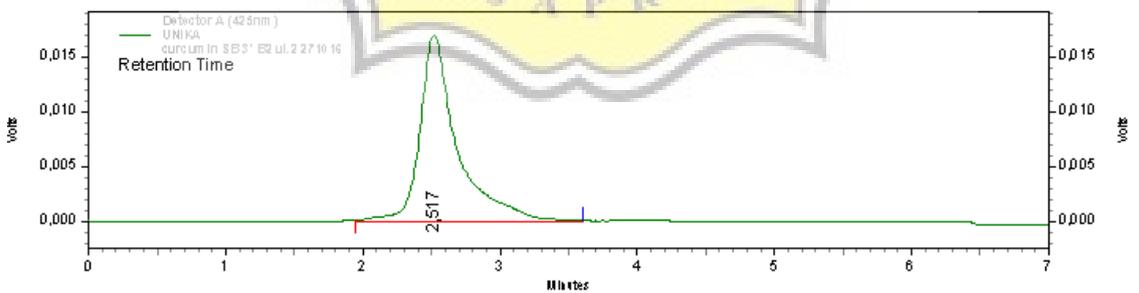
(e) Curcuma soaked 1% citric acid solution for 10 minutes



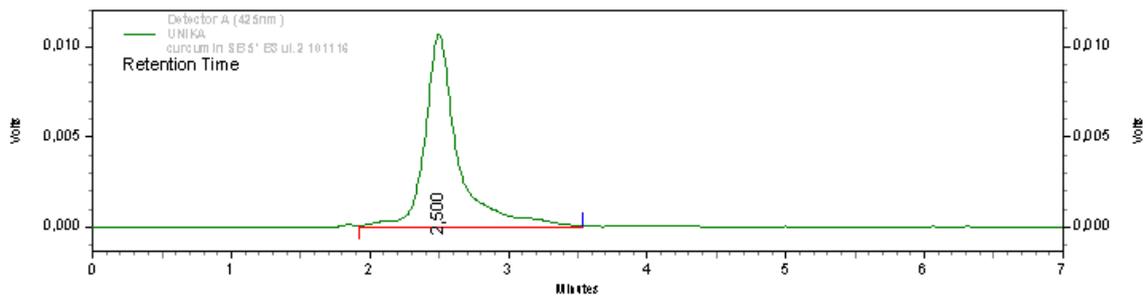
(f) Curcuma soaked 1% citric acid solution for 20 minutes



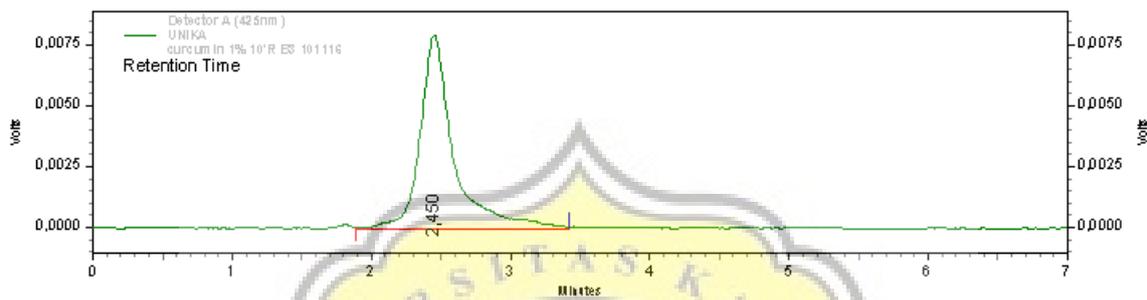
(g) Curcuma soaked 1% citric acid solution for 30 minutes



(h) Curcuma steam blanched for 3 minutes



(i) Curcuma steam blanched for 5 minutes



(j) Curcuma steam blanched for 10 minutes

Figure 11. Chromatograms of curcumin contents in curcuma after drying process

The dry basis of curcumin contents from the curcuma before and after drying process using HPLC and spectrophotometer can be seen in Table 3.

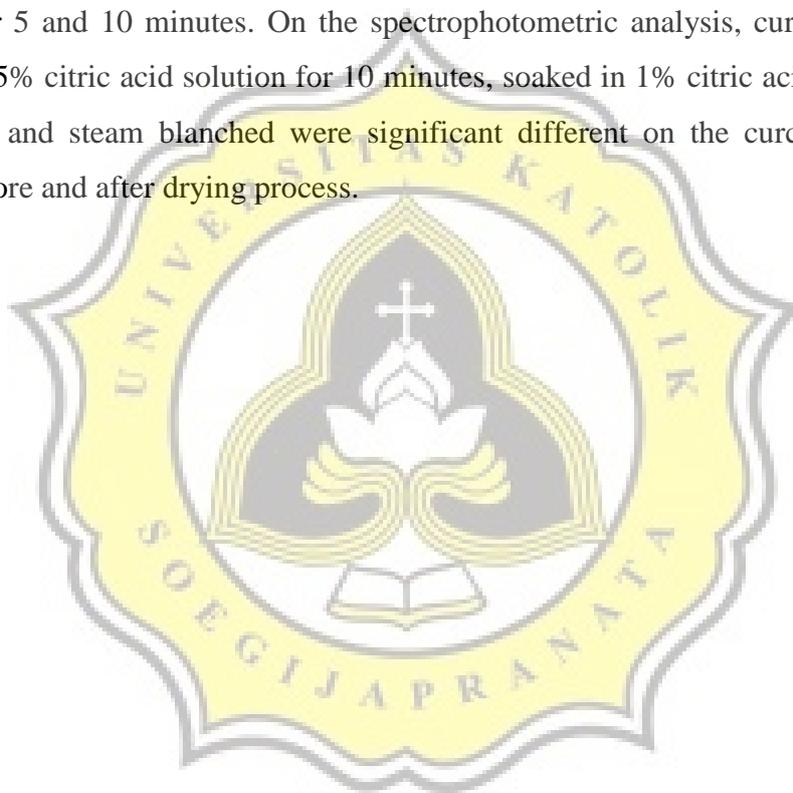
Table 3. Curcumin Contents Before and After Drying Process Using HPLC and Spectrophotometer

Treatment	Curcumin Content (ppm) (Dry Basis)			
	HPLC		Spectrophotometer	
	Before Drying	After Drying	Before Drying	After Drying
C0	12366.41 ± 884.43 ^{ab,NS}	14562.83±1942.81 ^{d,NS}	10349.91± 724.91 ^{ab,S}	12562.19±1330.52 ^{b,S}
C1A	14018.77 ±1223.39 ^{ab,NS}	13760.87±1095.32 ^{cd,NS}	7907.92± 954.62 ^{a,S}	12593.13±1835.24 ^{b,S}
C1B	15855.64 ±1764.69 ^{ab,NS}	12541.16±2568.39 ^{bcd,NS}	16170.82±1045.34 ^{d,NS}	17016.32± 814.90 ^{d,NS}
C1C	9091.27 ±5391.34 ^{a,NS}	12218.36±2740.59 ^{bcd,NS}	11095.74±1970.89 ^{abc,NS}	11952.58±2116.75 ^{b,NS}
C2A	12372.04 ±5439.45 ^{ab,NS}	10646.11±1810.38 ^{ab,NS}	12699.46±1805.73 ^{bcd,NS}	11181.64±1122.51 ^{ab,NS}
C2B	9315.92 ±4548.98 ^{a,NS}	15054.21±1939.29 ^{d,NS}	9478.79±1281.29 ^{ab,NS}	15283.80± 964.88 ^{c,NS}
C2C	17999.46 ±1673.22 ^{b,NS}	11327.55± 556.19 ^{bc,NS}	19966.03±1324.48 ^{e,S}	17759.35 ± 214.30 ^{d,S}
C3A	13230.73 ±3302.92 ^{ab,NS}	8274.18±1615.15 ^{a,NS}	14222.02±2025.50 ^{cd,S}	10152.42±1973.88 ^{a,S}
C3B	16237.64 ± 363.98 ^{ab,S}	9955.15±2069.77 ^{ab,S}	15481.19±2924.55 ^{d,S}	10977.04±1289.77 ^{ab,S}
C3C	29173.08 ±1105.39 ^{c,S}	14562.83±1942.81 ^{d,S}	24831.45±7929.40 ^{f,S}	12415.30± 691.41 ^{b,S}

Description:

1. All values are average ± standard deviation
2. Value with different superscript in columns show significant differences in the confidence level of $\alpha = 0.05$, NS= Non-significant and S=Significant, the value between before and after drying.
3. Treatment C0 = control; C1A = 0.5% citric acid soaking 10'; C1B = 0.5% citric acid soaking 20'; C1C = 0.5% citric acid soaking 30'; C2A = 1% citric acid soaking 10'; C2B = 1% citric acid soaking 20'; C2C = 1% citric acid soaking 30'; C3A = steam blanching 3'; C3B = steam blanching 5'; C3C = steam blanching 10'

Based on Table 3., we can see that the dry basis of curcumin contents before and after drying process. Both HPLC and spectrophotometer, curcuma soaked in 1% citric acid for 30 minutes (C2C) after drying process had the highest level of curcumin content. The curcumin content of curcuma steam blanched for 10 minutes before drying process was highest. For HPLC, curcuma soaked in 0.5% citric acid solution for 30 minutes (C1C) before the drying process had the lowest curcumin content. However, curcuma steam blanched after drying process for 5 minutes (C3B) had the lowest level of curcumin content. The result of SPSS shows that there was significant difference between curcumin content before and after drying process on the curcuma steam blanched for 5 and 10 minutes. On the spectrophotometric analysis, curcuma control, soaked in 0.5% citric acid solution for 10 minutes, soaked in 1% citric acid solution for 30 minutes, and steam blanched were significant different on the curcumin content between before and after drying process.



3.5. Water Activity

The result of water activity of curcuma before and after drying can be seen in Table 4.

Table 4. Water Activity of Curcuma Before and After Drying Process

Treatment	Water Activity	
	Before Drying	After Drying
C0	0.982±0.003 ^{b,S}	0.474±0.008 ^{bc,S}
C1A	0.993±0.005 ^{c,S}	0.505±0.048 ^{c,S}
C1B	0.987±0.004 ^{bc,S}	0.465±0.059 ^{abc,S}
C1C	0.990±0.003 ^{c,S}	0.478±0.063 ^{bc,S}
C2A	0.972±0.007 ^{a,S}	0.434±0.040 ^{ab,S}
C2B	0.971±0.012 ^{a,S}	0.493±0.016 ^{c,S}
C2C	0.981±0.007 ^{b,S}	0.460±0.013 ^{abc,S}
C3A	0.982±0.004 ^{b,S}	0.477±0.024 ^{bc,S}
C3B	0.990±0.001 ^{c,S}	0.480±0.027 ^{bc,S}
C3C	0.980±0.002 ^{b,S}	0.422±0.006 ^{a,S}

Description:

1. All values are average \pm standard deviation
2. Value with different superscript in each condition show significant differences in the confidence level of $\alpha = 0.05$, NS= Non-significant and S=Significant, the value between before and after drying.
3. Treatment C0 = control; C1A = 0.5% citric acid soaking 10'; C1B = 0.5% citric acid soaking 20'; C1C = 0.5% citric acid soaking 30'; C2A = 1% citric acid soaking 10'; C2B = 1% citric acid soaking 20'; C2C = 1% citric acid soaking 30'; C3A = steam blanching 3'; C3B = steam blanching 5'; C3C = steam blanching 10'

Based on Table 4., we can see water activity of curcuma before drying is higher than curcuma after drying process. The water activity level of curcuma before drying is around 0.971 until 0.990, whereas curcuma after drying process is around 0.422 until 0.505. Before drying process, curcuma soaked in 1% citric acid solution for 10 minutes (C2A) has the lowest level of water activity and curcuma soaked in 0.5% citric acid solution for 10 minutes(C1A) has the highest level of water activity. After the drying process, curcuma steam blanched for 10 minutes (C3C) has the lowest level of water activity and curcuma without pretreatment (control) has the highest level of water activity. There was significant different on the water activity between curcuma before and after drying process.