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Research article

Development of Khlu (*Pluchea indica* (L.) Less.) Leaves Drying Technology for Khlu Leaf Tea Production in Palian River Basin Community, Trang Province.

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Abstract: This research aims to investigate the optimal temperature conditions for drying Khlu (*Pluchea indica* (L.) Less.) leaves (KLs) in a laboratory, develop KLs drying technology, and transfer the technology to the Palian River Basin Community in Trang Province. The results showed that after drying KLs at different temperatures for 7 hours, the optimal was 45°C, which resulted in a moisture content of 10.95 ± 0.54%, a lightness (L) value of 48.87 ± 1.58, and the lowest effective concentration (EC_{50}) of 0.200 ± 0.024 mg/mL. Drying at 55°C produced results similar to drying at 45°C, with a moisture content of 10.16 ± 1.27%, a lightness (L) value of 35.33 ± 1.75, and an EC_{50} of 0.370 ± 0.003 mg/mL. Drying at 65°C wasn't as effective. At the same time, the KLs had a low moisture content of 9.40 ± 1.24%, they turned out very dark (L value = 34.33 ± 0.38), and they also had the highest EC_{50} of 0.730 ± 0.007 mg/mL, indicating the weakest antioxidant ability. The KLs drying technology can utilize sunlight and heat from biomass to reduce the moisture content to just 5.80 ± 0.61% and 7.02 ± 1.97%, respectively, and has an EC_{50} of 0.240 ± 0.011 mg/mL and 0.290 ± 0.010 mg/mL, respectively. Finally, the researchers transferred the KLs drying technology to the community for drying KLs to produce Khlu leaf tea. This technology can dry about 10 kg of fresh KLs per period. Upon drying, the technology is expected to yield approximately 2 kg of dried KLs for the production of Khlu leaf tea.

Keywords: Khlu leaf (KLs); Drying technology; Khlu leaf tea; Palian river basin community

1. Introduction

The use of herbal plants is becoming increasingly popular, with applications in medicine, food, cosmetics, and beverages. In particular, herbal plants are being processed into herbal teas, which are widely consumed. These teas are made from herbs known for their health benefits, which undergo a drying process to preserve their properties. The tea is consumed by rehydrating the herbs in hot or cold water. Nowadays, the consumption of Thai herbal teas has increased, particularly among older individuals, who drink them for their health benefits. Many types of plants have been processed into herbal teas, such as Mulberry leaf, Shallots, Crossandra, Safflower, Pandan leaf, and Gymnema [1- 6]. Khlu (*Pluchea indica* (L.) Less.) (Fig. 1) is a variety of plant that belongs to the Asteraceae family. This shrub grows to a height of 1-2 meters and is commonly found in tropical regions, including Africa, Asia, the America, Australia, and southern China. It has various local names, including Khlu (Thai), Kuo bao ju (Chinese), Kukrakonda (Bengali), and Beluntas (Bahasa) [7]. Khlu is a semi-mangrove plant that can thrive both in water and on land. Khlu leaves (KLs) are used to make healthy drinks and as a traditional herbal medicine, especially in Southeast Asia, including Thailand. KLs have medicinal properties used to treat inflammation, diabetes, cholera, arthritis, vaginal discharge, bad breath, body odor, pus, abscesses, and diarrhea, among other conditions [8-10]. Additionally, in Thailand, KLs are commonly used as a key ingredient in various local dishes. [11]. In the Palian River Basin, Trang Province, it is considered an area where KLs are found growing widely. In the past, villagers in the Palian River Basin community would eat KLs with chili paste or use them as an ingredient in cooking or even as medicine. The Palian River Basin community in Trang Province, specifically in Ban Hin Khok Khwai, Ban Na Subdistrict, Palian District, Trang Province, recognizes the value and importance of KLs by producing Khlu leaf tea products to generate income for the community. However, the community faces limitations in production due to quality issues with the raw materials, as the process of drying KLs must be performed before the production of Khlu leaf tea products can begin. However, there are problems during certain periods, such as when there is no sun or during the rainy season. If the raw materials cannot be dried in the sun, this results in the inability to produce products continuously. Therefore, this research aims to investigate the optimal conditions for preparing usable raw materials to produce high-quality Khlu leaf tea at the laboratory level. After that, a Khlu leaf drying system will be designed and constructed to obtain quality dried KLs and transfer the technology for use in producing Khlu leaf tea in the Palian River Basin community, Trang Province.

Figure 1. Khlu (*Pluchea indica* (L.) Less.) (Photo by the author)

2. Materials and Methods

2.1 Preliminary study of KLs

Samples of KLs were collected from the Ban Hin Khok Khwai community, Ban Na sub-district, Palian district, Trang province. Only the leaf parts of the Khlu were collected, washed with clean water, and drained. After that, they were packed in plastic bags and refrigerated at 5 ± 2°C for analysis of the basic characteristics of KLs. The moisture content of the KLs was determined by weighing an aluminum cup that had been dried to a constant weight and recording the weight. Weigh the sample into an aluminum cup with 2 grams and record the weight. The sample was placed in a hot air oven (Binder ED56, Germany) with the lid of the aluminum cup partially open. The hot air oven was heated at 105°C until the sample weight was constant. The moisture content was calculated using the AOAC method [12], and color values were obtained using a colorimeter (Konica Minolta CR-10, Japan).

2.2 Study of the optimum drying conditions for KLs in the laboratory

The research on the best drying conditions for KLs was based on the method used by Polyium and Sakulyunyongsuk [13], who dried KLs at various temperatures for 7 hours. The procedure will result in the production of KLs with a moisture content of not more than 10%. The study by Podkumnerd et al. [14] found that the drying of products in the solar dryer cabinet in the Palian River Basin area had temperatures ranging from 40.8°C to 57.2°C. Before developing the KLs drying technology, the researchers tested the optimal drying conditions in the lab using a hot air oven (Binder ED56, Germany) by varying the temperature to 45°C, 55°C, and 65°C for 7 hours. Samples were collected every hour for analysis of physical components, including moisture content, using the AOAC method [12], and color value using a colorimeter (Konica Minolta CR-10, Japan). Chemical composition analysis involved examining antioxidant activity using DPPH assays, starting from sample extraction, which was modified from the method of Sawaengkhot et al. [12]. This method involved extracting 5 g of KLs with boiling water (temperature 100°C) for 30 minutes. Next, we centrifuged the extract (Nuve CN 180, Turkiye) at 5,000 rpm for 10 minutes and filtered it using filter paper No. 1 (Whatman, Germany). The sample was stored in a tightly closed bottle at -20°C. Then, the antioxidant activity was assessed using DPPH assays, adapted from the method of Sawaengkhot et al. [15]. An extracted sample (1 mL) from KLs was aspirated into a test tube by mixing with 200 µL of DPPH (2,2-diphenyl-1-picrylhydrazyl) solution and leaving it in the dark for 30 minutes. The absorbance was measured using a spectrophotometer (BMG LABTECH SPECTROstar Nano, Germany) at a wavelength of 515 nm. The data were examined for differences using one-way ANOVA, and the differences between group averages were checked with Duncan's Multiple Range Test (DMRT) at a significance level of 0.05.

2.3 Design and development of KLs drying technology

The researchers used the data on the appropriate temperature conditions for drying KLs from section 2.2 to design KLs drying technology that works in all weather conditions, both with and without sunlight. After designing the KLs drying technology, the researchers created its prototype. They tested the efficiency of the system by studying the temperature changes in the drying system using a thermometer (PHYWE Cobra SMARTsense Temperature, Germany), the moisture content of the KLs using the AOAC method [12], the color value of the KLs using a colorimeter (Konica Minolta CR-10, Japan), and studying the antioxidant activity using the DPPH assays. We analyzed the data for differences between the means of the two conditions using the independent t-test, maintaining a significance level of 0.01. Finally, an analysis of microbe yeast and mold was done according to the AOAC method [12].

2.4 Technology transfer to the community

When the development of KLs drying technology was completed, the researchers transferred to the Palian River Basin Community in Trang Province, specifically to the area of Ban Hin Khok Khwai, Ban Na Subdistrict, Palian District, Trang Province, so that the community could utilize it for Khlu leaf tea production.

3. Results and Discussion

3.1 Results of the preliminary study of KLs

Based on the study of the basic features of KLs shown in Table 1, it was found that KLs had an average moisture content of 83.21 ± 0.27% and a brightness (L) of 52.95 ± 0.54, with a* and b* values of -3.50 ± 0.40 and 34.29 ± 1.06, respectively. KLs were dark green (Figure 2A), which indicates that a* values were negative. It can be seen that the KLs have a relatively high moisture content because they are plants that grow in wetlands, which is consistent with the research of Polyium and Sakulyunyongsuk [13], who found that the KLs used to produce Khlu tea from the Phraek Nam Daeng community, Amphawa District, Samut Songkhram Province, have a moisture content of 60.78±0.24%.

Table 1. Results of the study on the characteristics of KLs.

Basic characteristics of KLs	Amount
Moisture content (%)	83.21 ± 0.27
L (Brightness)	52.95 ± 0.54
a*	-3.50 ± 0.40
b*	34.29 ± 1.06

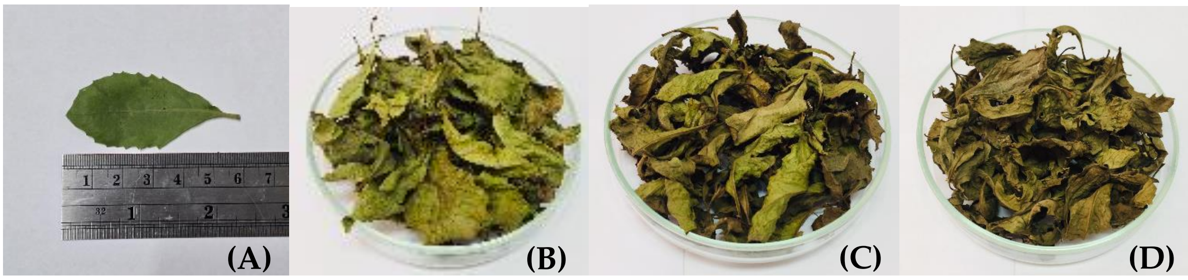

Figure 2. Characteristics of KLs in various conditions: A) Fresh KLs, B) dried at 45 °C, C) dried at 55 °C, and D) dried at 65 °C

3.2 Results of the study on the optimum drying conditions for KLs

Drying is widely used in various thermal energy applications, ranging from food drying to the drying of wood. To improve moisture migration from within the product, the dryer's goal is to provide the product with more heat than is possible in ambient settings. This process will increase the vapor pressure of the moisture contained within the product [16]. Based on the results of the moisture content of dried KLs in a hot air oven with varied temperatures at three different levels (45°C, 55°C, and 65°C), as shown in Table 2, it was found that the initial moisture content ranged from 82.12 ± 0.69% to 83.21 ± 0.27%. The moisture content gradually decreased over time. Then, the moisture content gradually remained constant after 7 hours. At 45°C, KLs had a moisture content of 10.95 ± 0.54%; at 55°C, the moisture content was 10.16 ± 1.27%; and at 65°C, the moisture content was 9.40 ± 1.24%.

Table 2. The moisture content of KLs at different temperatures

Time (Hour)	The moisture content (%)		
	45°C (Mean ± S.D.)	55°C (Mean ± S.D.)	65°C (Mean ± S.D.)
0	82.86 ± 1.04	82.14 ± 1.12	82.85 ± 1.07
1	82.14 ± 3.13	80.70 ± 1.05	76.63 ± 3.07
2	74.64 ± 1.01	70.71 ± 0.94	72.14 ± 0.93
3	58.21 ± 3.42	68.57 ± 1.03	69.29 ± 1.01
4	42.50 ± 1.54	34.29 ± 2.53	29.29 ± 1.00
5	35.00 ± 0.85	24.29 ± 4.14	20.36 ± 3.05
6	12.50 ± 0.82	11.43 ± 1.05	10.71 ± 0.93
7	10.95 ± 0.54	10.16 ± 1.27	9.40 ± 1.24

The characteristics of KLs at different temperatures and times varied in terms of L (brightness), a* (redness), and b* (yellowness) values. As shown in Table 3, the L value at 45°C, which was 52.95 ± 0.54, decreased to 48.87 ± 1.58 after 7 hours. The a* value, initially -3.33 ± 0.49, increased to -1.50 ± 0.30, while the b* value, initially 34.29 ± 1.06, decreased to 28.04 ± 6.49. KLs at 55°C showed the L value of 52.95 ± 0.54 decreased to 35.33 ± 1.75, the a* value of -3.33 ± 0.49 increased to 5.37 ± 0.40, and the b* value of 34.29 ± 1.06 decreased to 16.23 ± 0.93 after 7 hours. KLs at 55°C showed the L value of 52.95 ± 0.54 decreased to 35.33 ± 1.75, the a* value of -3.33 ± 0.49 increased to 5.37 ± 0.40, and the b* value of 34.29 ± 1.06 decreased to 16.23 ± 0.93 after 7 hours. KLs at 65°C, the characteristics of the L value were 52.95 ± 0.54, which decreased to 34.33 ± 0.38; the a* value was -3.33 ± 0.49, which increased to 8.23 ± 0.35; and the b* value was 34.29 ± 1.06, which decreased to 15.44 ± 0.26 after 7 hours. From the experiment, we can see that raising the drying temperature of KLs resulted in their color becoming darker (Fig. 2), as indicated by the lower L and b* values and the higher a* values. This conclusion is consistent with the research of Punchuklang *et al*. [17], who found that when the drying time of young shoots of *Crotalaria juncea* was increased, the tea powder dried at a higher temperature had decreased L and b* values and increased a* as well.

Table 3. Color characteristics of KLs in the laboratory

Temperature (°C)	Time (Hour)	Color		
		L	a*	b*
45	0	52.95 ± 0.54	-3.33 ± 0.49	34.29 ± 1.06
	1	52.28 ± 0.65	-3.06 ± 0.10	33.77 ± 2.36
	2	51.50 ± 1.35	-2.67± 0.65	32.67± 1.46
	3	51.40 ± 1.35	-2.53 ± 0.58	31.29 ± 1.17
	4	50.16 ± 1.44	-2.41 ±0.12	30.80 ± 1.31
	5	49.67 ± 0.47	-1.87 ± 0.21	30.23 ± 0.87
	6	49.03 ± 1.34	-1.72 ± 0.11	28.23 ± 0.21
	7	48.87 ± 1.58	-1.50 ± 0.30	28.04 ± 6.49
55	0	52.95 ± 0.54	-3.33 ± 0.49	34.29 ± 1.06
	1	41.70 ± 1.41	-2.90 ± 0.26	23.33 ± 1.95
	2	40.53 ± 0.91	-2.04 ± 0.09	19.58 ± 0.67
	3	37.57 ± 0.97	3.00 ± 1.00	18.23 ± 2.71
	4	37.20± 0.88	4.69 ± 0.19	17.47 ± 0.61
	5	37.00 ± 1.61	5.23 ± 0.42	17.03 ± 0.68
	6	36.77 ± 1.03	5.27 ± 0.25	16.47 ± 0.76
	7	35.33 ± 1.75	5.37 ± 0.40	16.23 ± 0.93
65	0	52.95 ± 0.54	-3.33 ± 0.49	34.29 ± 1.06
	1	41.73 ± 1.16	6.97 ± 0.15	19.60 ± 0.75
	2	40.43 ± 0.69	7.24 ± 0.24	19.09 ± 0.38
	3	37.53 ± 0.75	7.43 ± 0.32	18.80 ± 0.56
	4	37.07 ± 0.40	7.57 ± 0.31	17.86 ± 0.16
	5	36.4 ± 2.65	8.07 ± 0.40	16.80 ± 0.26
	6	35.23 ± 0.70	8.14 ± 0.38	16.10 ± 0.36
	7	34.33 ± 0.38	8.23 ± 0.35	15.44 ± 0.26

One of the most significant variables influencing antioxidant activity is temperature. Generally, it is thought that heating causes an acceleration of the initiation reactions and hence a decrease in the activity of the present or added antioxidants. However, temperature variations may alter the modes of action of some antioxidants or have differing effects on them. [18-19]. The effective concentration (EC_{50}) is the concentration that reduces the concentration of DPPH free radicals by 50%. Therefore, the EC_{50} indicates good antioxidation performance [20, 21]. From drying the KLs at 45°C, 55°C, and 65°C for 7 hours, which gave the moisture content of dried KLs of 10.95%, 10.16%, and 9.40%, respectively, this amount of moisture meets the criteria for tea products from plants according to the Thai community product standard (1466/2556) [22], which must not contain more than 10% moisture. Therefore, the researchers analyzed the antioxidant activity of dried KLs at three different temperatures. The analysis of how drying temperatures of dried KLs affect DPPH radical scavenging activity (Table 4) revealed that these temperatures significantly influence the EC_{50} of the dried KLs. The dried KLs dried at 65°C gave the highest EC_{50} of 0.730 ± 0.007 mg/mL, which was different from the other sample at a significance level of 0.05, followed by the dried KLs dried at 55°C with an EC_{50} of 0.370 ± 0.003 mg/mL, and followed by the dried KLs dried at 45°C with an EC_{50} of 0.200 ± 0.024 mg/mL. From the data, it can be seen that dried leaves dried at 45°C have the lowest EC_{50}, indicating the highest efficiency in antioxidation. The dried KLs at 55°C had the second-best efficiency. In contrast, those dried at 65°C had the least efficiency in antioxidation, which matches the findings of Noitubtim et al. [1], who discovered that drying mulberry tea leaves at higher temperatures resulted in higher EC_{50} values, indicating a decrease in antioxidant activity. This indicates that temperature has a significant impact on the degradation of antioxidant compounds.

Table 4. Effect of drying temperatures of dried KLs on DPPH radical scavenging activity

Temperature (°C)	EC_{50}* (mg/mL)
45	0.200 ± 0.024^{a}
55	0.370 ± 0.003^{b}
65	0.730 ± 0.007^{c}

* Different characters in each column illustrated the average comparison by DMRT at a significantly different level of 0.05

3.3 Design and development of KLs drying technology

As regards the study of the appropriate conditions for producing dried KLs, it was found that temperature has a significant effect on the composition of important substances in KLs. The temperature must not be too high to destroy antioxidants, which are beneficial substances. The study indicated that the optimal temperature for drying KLs is between 45°C and 55°C for 7 hours, which maintains the moisture content at 10%, complies with the Thai community product standard 1466/2566 [22], and ensures that the dried KLs remain light in color. Additionally, these KLs exhibit better antioxidation properties compared to those dried at 65°C. The researchers developed a drying method for KLs that is effective regardless of the weather conditions. Additionally, they exhibited higher antioxidant efficiency than those dried at 65°C. The researchers designed the KLs drying technology, which can dry KLs efficiently regardless of weather conditions. Figure 3 displays the researchers' draft of the KLs drying technology.

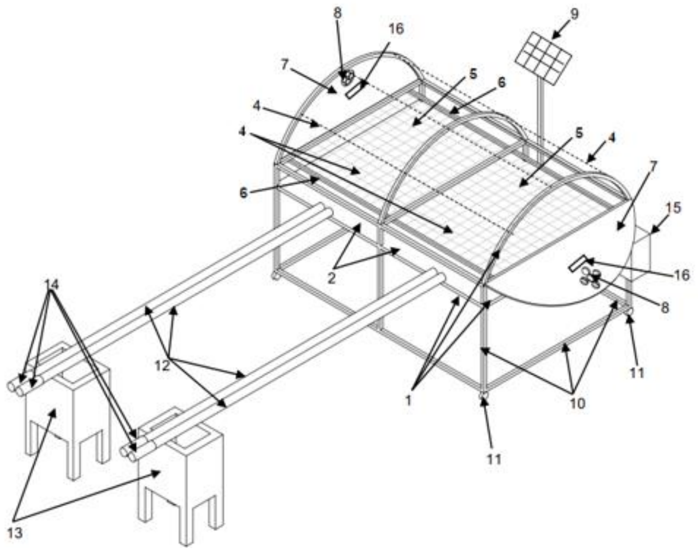

Figure 3. The schematic of KLs drying technology consists of: 1) Oven structure 2) Side walls 4) Roof 5) Oven chamber 6) Drying panel rails 7) Door 8) Dehumidification fan 9) Solar panels 10) Cabinet structure support 11) Casters 12) Heat transfer steel pipe 13) Biomass stove 14) Heat transfer fan 15) Oven temperature control system and 16) Door handle

This KL's drying technology is a drying system that utilizes solar energy in combination with biomass energy. The working principle is divided into two parts: the first part is the body structure, which consists of a square metal frame that is assembled and connected to a base with wheels. The front wall, side walls, and bottom wall are covered with metal sheets. The top wall of the body structure features a curved roof covered with clear polycarbonate sheets, allowing for good natural light. The inside of the body structure is divided into two drying chambers. Each room is equipped with one drying panel for drying KLs, and a steel rail is installed along the front wall to the back of the house structure, allowing the drying panel to be placed in the drying room and slid in and out conveniently. There is a second part that increases the heat. The installation of the heating system utilizes hot air generated by burning steel pipes sourced from biomass, such as wood chips, in a biomass stove. The heat accumulated in the steel pipes is transferred to the drying room using a heat fan installed at the end of the steel pipe, which blows hot air into the drying room. There is a temperature sensor that orders the heat fan to stop working when the temperature in the drying room exceeds the specified temperature. After the design was completed, the researchers proceeded to create KLs drying technology, as shown in Figure 4.

Figure 4. Prototype of KLs drying technology: A) Using solar energy, B) Temperature control system, and C) Using heat from biomass

After designing and prototyping the KL drying technology, the researchers tested the system's performance under both sunlight and non-sunlight conditions by setting the temperature control inside the dryer to a maximum of 55°C. After examining the temperature inside KLs's drying technology for drying KLs within a drying time of 7 hours, it was found that the temperature inside the dryer under the condition of using solar energy (with sunlight) was close to that of using heat from biomass (without sunlight), which gave temperatures of 54.70 ± 0.28°C and 53.85 ± 0.92°C, respectively (data shown in Table 5).

Table 5. Study of temperature inside KLs drying technology under different conditions

Time (Hour)	Temperature (°C)	
	Solar energy (With sunlight)	**Heat from biomass (Without sunlight)**
0	44.00 ± 2.40	32.95 ± 0.64
1	49.25 ± 2.76	40.25 ± 0.64
2	49.70 ± 1.41	45.95 ± 0.92
3	51.30 ± 1.13	46.70 ± 0.42
4	52.10 ± 1.84	47.90 ± 0.35
5	52.15 ± 2.33	52.35 ± 0.07
6	54.80 ± 1.13	54.20 ± 1.13
7	54.70 ± 0.28	53.85 ± 0.92

The study of the moisture content of dried KLs using KLs drying technology (data shown in Table 6) revealed that dried KLs, utilizing solar energy and heat from biomass, can effectively reduce the moisture content in KLs. Dried KLs using solar energy had a moisture content of 8.35 ± 1.00%, and dried KLs using heat from biomass had a moisture content of 10.10 ± 0.92% after drying for only 5 hours. When dried for 7 hours, it was found that dried KLs using solar energy and heat from biomass had a moisture content of only 5.80 ± 0.61% and 7.02 ± 1.97%, respectively. From the experimental results, it can be seen that the use of this KLs drying technology can reduce the moisture content of KLs quickly, which is consistent with Podkumnerd *et al*. [14] who found that the use of the Nipa leaf drying system for use during sunlight and without sunlight can reduce the moisture content of Nipa leaf faster than natural sunlight drying. The reduction of moisture content to up to 10% in 4 hours.

Table 6. Moisture content of dried KLs using KLs drying technology in different conditions

Time (Hour)	Moisture content (%)	
	Solar energy (With sunlight)	**Heat from biomass (Without sunlight)**
0	80.14 ± 1.32	81.20 ± 1.14
1	67.16 ± 1.01	77.37 ± 2.01
2	53.28 ± 1.59	65.79 ± 1.89
3	32.65 ± 2.37	46.92 ± 1.48
4	20.08 ± 2.61	26.48 ± 2.92
5	8.35 ± 1.00	10.10 ± 0.92
6	5.97 ± 0.62	8.94 ± 0.17
7	5.80 ± 0.61	7.02 ± 1.97

The study of the color characteristics of dried KLs by KLs drying technology for 7 hours (Table 7) showed that dried KLs using solar energy (with sunlight) had L values (brightness) of 40.43 ± 0.69, a* values of 12.40 ± 0.52, and b* values of 19.09 ± 0.38, which were similar to dried KLs using heat from biomass (without sunlight), L values of 41.37 ± 0.91, a* values of 12.60 ± 1.28, and b* values of 18.60 ± 0.26.

Table 7. Results of the color values of KLs in KLs drying technology in different conditions

Time (Hour)	Solar energy (With sunlight)			Heat from biomass (Without sunlight)		
	L	**a***	**b***	**L**	**a***	**b***
0	51.95 ± 0.74	-3.00 ± 0.10	31.29 ± 1.17	51.50 ± 1.35	-2.67 ± 0.65	32.67 ± 1.46
1	44.47 ± 1.29	-3.57 ± 0.55	23.33 ± 1.95	45.60 ± 1.93	-2.04 ± 0.09	23.33 ± 1.95
2	43.57 ± 0.76	6.97 ± 0.15	23.13 ± 0.67	43.77 ± 1.67	7.24 ± 0.24	22.83 ± 1.16
3	43.03 ± 0.57	10.23 ± 0.32	22.70 ± 1.54	42.23 ± 0.42	10.30 ± 1.41	22.40 ± 0.87
4	42.60 ± 2.91	10.60 ± 0.26	22.57 ± 2.31	42.20 ± 1.39	11.57 ± 1.46	21.80 ± 0.72
5	42.47 ± 1.08	11.43 ± 1.62	21.67 ± 0.90	41.93 ± 0.70	11.77 ± 1.39	61.63 ± 0.80
6	40.53 ± 0.91	11.57 ± 0.81	19.58 ± 0.67	41.73 ± 1.16	12.03 ± 0.68	19.60 ± 0.75
7	40.43 ± 0.69	12.40 ± 0.52	19.09 ± 0.38	41.37 ± 0.91	12.60 ± 1.28	18.60 ± 0.26

From the effect on drying of dried KLs on DPPH radical scavenging activity (Table 8), an EC_{50} of the dried KLs using solar energy was 0.240±0.011 mg/mL, which was different at a significance level of 0.01 from the dried KLs using heat from biomass with an EC_{50} of 0.290±0.010 mg/mL. Furthermore, this technology yielded similar results to the dried KLs obtained by drying with a hot air oven at 45°C and 55°C (data shown in Table 4), which resulted in EC_{50} values of 0.200 ± 0.024 and 0.370 ± 0.003 mg/mL, respectively. From the EC_{50} of dried KLs obtained by KLs drying technology using solar energy and heat from biomass, it can be seen that the dried KLs obtained by this technology still retain antioxidant content comparable to that obtained by laboratory drying.

Table 8. Effect of drying of dried KLs using KLs drying technology on DPPH radical scavenging activity

Conditions	EC_{50} (mg/mL)	t	p-value
Solar energy	0.240 ± 0.011	-5.826**	0.004
Heat from biomass	0.290 ± 0.010		

**The mean difference is significant at the 0.01 level

The results of the study on microbial contamination in dried KLs using KLs drying technology showed that the technology was effective in reducing microbial contamination (data were shown in Table 9). Dried KLs using solar energy (with sunlight) had a total microbial count of 423.33 ± 75.06 (cfu/g) and yeast and mold counts of 63.33 ± 15.28 (cfu/g). Dried KLs produced using heat from biomass (without sunlight) had a total microbial count of 540.00 ± 75.50 (cfu/g) and yeast and mold counts of 86.67 ± 11.55 (cfu/g). The amount of microbes detected in dried KLs using this technology was within the Thai community product standard 1466-2556 (dried Gymnema for infusion), which specifies a total amount of microbes not exceeding 1 x 10^4 (cfu/g) and yeast and molds less than 100 (cfu/g) [22].

Table 9. Microbial quality of dried KLs by using KLs drying technology

Microbial	Solar energy (With sunlight)	Heat from biomass (Without sunlight)
Total microbial (cfu/g)	423.33 ± 75.06	63.33 ± 15.28
Yeast and mold (cfu/g)	540.00 ± 75.50	86.67 ± 11.55

From the development of the KLs drying technology, which can produce dried KLs under conditions with sunlight using solar energy and in conditions without sunlight using heat from biomass, the researchers compared the efficiency of the two drying systems (Table 10). They found that both drying systems can dry fresh KLs at a rate of approximately 10 kg per hour, and after 7 hours, the amount of dried KLs will be approximately the same. The KLs' drying technology using solar energy will produce an average of 1.94 kg of dried KLs, and the drying using biomass heat energy will produce an average of 2.13 kg of dry KLs. However, drying using heat from biomass energy will cost slightly more than using biomass, such as dry wood, which, when calculated as the cost of procurement, will cost approximately 0.8 baht/kg. The drying process that uses rubberwood as fuel will require approximately 25 kg of rubberwood per production cycle. However, if the community can procure fuel from dry wood scraps, this will reduce the cost in this part. When considering the installation cost, it was found that the KLs drying technology using solar energy would cost approximately 18,000 baht. If a drying system using heat from biomass is installed, the cost would be approximately 30,000 baht. However, even though the installation of KLs drying technology using heat from biomass would increase the installation cost, the advantage is that the community can produce dried KLs all the time, resulting in increased income for the community.

Table 10. Comparative analysis of the efficiency of KLs drying technology in different conditions

	Solar energy (With sunlight)	Heat from biomass (Without sunlight)
Fresh KLs (kg)	10.00	10.00
Dried KLs (kg)	1.94	2.13
Fuel costs (baht)	-	20.50
Installation cost (baht)	18,000.00	30,000.00

3.4 Transfer of KLs drying technology to the community

The researchers had transferred KLs drying technology for producing Khlu leaf tea to the target group, which is the fishery group that collects and preserves Khlu shells, Ban Hin Khok Khwai, Ban Na Subdistrict, Palian District, Trang Province (Figure 5), along with developing production process techniques to increase quality and consumer confidence, from collecting KLs, cleaning, and drying processes. The KLs drying technology can dry about 10 kg of fresh KLs per period. After drying, it will yield approximately 2 kg of dried KLs, which can be used to produce Khlu leaf tea. After transferring the technology to the community, locals can utilize it to increase production potential and distribute their products within Trang Province.

Figure 5. Transfer of KLs drying technology to the Palian River Basin Community, Trang Province

4. Conclusions

Upon examining the appropriate temperature conditions for drying KLs to obtain quality in the laboratory, it was found that the appropriate temperature for the KLs drying process was in the range of 45°C - 55°C for 7 hours, which was shown to produce dried KLs with only 10% moisture content and not too dark in color. From the data on the effect of drying temperatures on the DPPH radical scavenging activity of dried KLs, it can be seen that leaves dried at 45°C have the lowest EC_{50}, indicating the highest efficiency in antioxidation. The EC_{50} is the concentration that reduces the DPPH free radicals by 50%. The EC_{50} indicates good antioxidation performance. The dried KLs at 55°C had the second-best efficiency, while those dried at 65°C had the least efficiency in antioxidation. Through the results of KLs drying in the laboratory, the researchers were able to design and develop KLs drying technology that can function in both conditions, i.e., with sunlight and without sunlight. The researchers were able to control the temperature within the system to prevent it from exceeding 55°C, thereby achieving drying conditions similar to those in the laboratory. The test results were satisfactory. The drying method, which utilized sunlight and solar energy heat, and the other method, which employed additional heat from biomass, yielded results for temperature, moisture content of dried KLs, and EC_{50} that were comparable to those obtained in the laboratory. After that, the researchers transferred KLs drying technology to the Palian River Basin Community (the shellfishing and shellfish conservation group, Ban Hin Khok Khwai, Ban Na Sub-district, Palian District, Trang Province) for use in drying KLs to produce Khlu leaf tea. This technology can dry about 10 kg of fresh KLs per period. Upon drying, the technology is expected to yield approximately 2 kg of dried KLs for the production of Khlu leaf tea. During the period of sunlight, KLs drying technology can be used to dry Khlu leaves directly. When there is no sunlight or it is raining, the community can utilize this technology by employing free biomass as a heat source to dry KLs. This approach allows the community to continuously produce dried KLs for use in the production of Khlu leaf tea. As a result, the community can utilize local resources to generate a sustainable income.

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