

Effect of Drying Conditions on Qualities of Dried Wampee [*Clausena lansium* (Lour.) Skeels].

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ABSTRACT

Dried wampee becomes a well known preserved product of Nan province. The effects of 4 drying conditions on qualities of dried wampee were evaluated. Chosen drying conditions were hot air drying at 60°C, hot air drying at 45°C, vacuum drying at 45°C, and sun drying. Experiment on drying process revealed that drying times of drying conditions stated to reach 14 % (wb) moisture content were 17, 42, 50, and 32 h, respectively. The total change in product color, ΔE were observed to be 21.49, 13.72, 6.61, and, 12.75, respectively. Vacuum drying at 45°C, with 6.61 ΔE gave the best color of dried wampee but took the longest drying time. Sun drying had 12.75 ΔE which was reasonably good color and also had reasonable time of drying (32 h). Fifty consumer evaluation on these products using 9-points hedonic scale indicated that sun-dried wampee was the most significantly preferred product with 7.1 of overall acceptance. Analysis of the essential oils by GC-MS, obtained from fresh fruit (0.11%) and sundried fruits (0.50%), found 40 components. The major constituents were sabinene, α -pinene, and 1-phellandrene.

Key words: wampee, volatiles, GC-MS, sabinene, monoterpene.

INTRODUCTION

Food drying is one of the oldest methods of preserving food for later use. It is a complex operation involving heat and mass transfer which may cause changes in product quality. Physical changes that may occur include shrinkage, puffing and crystallization. In some cases, desirable or undesirable chemical or biochemical reactions may occur leading to changes in color, texture, odor or other properties of the food product (Maskan *et al.*, 2002). Drying occurs through vaporization of the liquid by supplying heat to the wet material. Heat may be supplied by conduction (contact or indirect dryers), by convection (direct dryers), by radiation or, volumetrically, by placing the wet material in

a microwave or radio frequency electromagnetic field. Over 85% of industrial dryers are of convection type with hot air or direct combustion gases as the drying medium (Devahastin, 2000). Drying of agricultural products has always been of great importance to the preservation of food by human being. Sun drying is still the most common method used to preserve agricultural products in most tropical and subtropical countries (Yaldiz *et al.*, 2001).

Wampee [*Clausena lansium* (Lour.) Skeels] is a minor member of the Rutaceae and distant relative of the citrus fruits originated in southern China. The Chinese people introduce it to the north of Thailand for more than 100 years in Nan province. It has many vernacular names and most

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are derived from the Chinese *huang-p'i-kuo*, in Thailand it is *mafai jeen*. The common name is *wampee*. The fruit tastes similar to grapefruit, when ripe, resembles a diminutive lemon, and is about 2 cm in diameter (Figure 1). It contains 1 – 3 seeds and the pulp is slightly acid. When fully ripe, it can be eaten with peel. The fruit is said to have been used as a medicine for stomach upset and indigestion, for cough, as folkloric uses in Philippines for influenza, cold and abdominal colic pain (Stuart,1977). In general, the fruit is sold at a price approximately 25 Bht/kg.

Because of the short harvest season, all of the wampee produced cannot be consumed immediately at harvesting time as fresh. Therefore, they must be preserved in some form for further use, i.e., their processing into other wampee derivatives is necessary. The pulp of wampee can be added to fruit cups, gelatins or other desserts, or made into pie, jam or jelly. Carbonated beverage resembling champagnes is made by fermenting the fruit with sugar (Morton, 1987), but the most popular product is in the dried form. Dried wampee is currently produced in Thailand as a sweet preserved fruit. Nevertheless, drying characteristics of wampee has not been studied. Therefore, the purpose of this study was to evaluate the effect of four drying methods; hot air drying at 60°C, hot air drying at 45°C, vacuum drying at 45°C and sundrying, on qualities of dried wampee fruits.



Figure 1 Wampee (*Clausena lansium* (Lour.) Skeels).

MATERIALS AND METHODS

1. Plant materials

The fresh Wampee fruits were collected in May 2004. Nan province located in the northern part of Thailand. The experiments were carried at Bangkok (13° 45' N, 100° 31' E)Thailand. All wampee fruits used in this experiment were from the same batch.

2. Preparation of dried wampee

Flow chart for dried wampee production is shown in Figure 2 The first step was washing of wampee to remove dirt, leaves, and foreign materials. Then, the wampee was soaked in 3% brine for 6 h. The fruits were separated from branched panicle and deseeded manually. The flesh with peel obtained was mixed with 35% sugar by weight. Then, it was rested for 2 h until sugar impregnated as flesh and drying later.

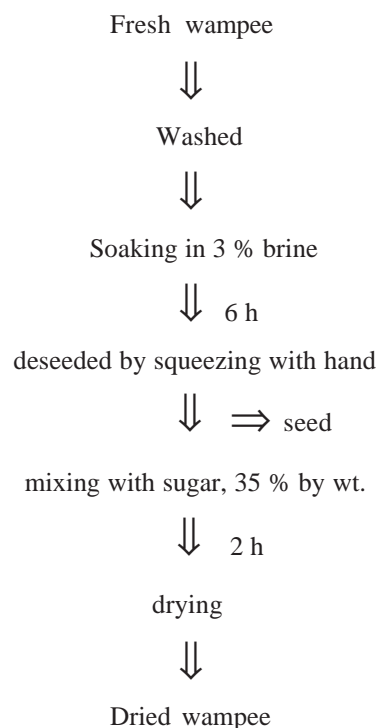


Figure 2 Flow chart of dried wampee process.

3. Drying

The wampee fruits were dried in a hot air dryer (BWS, B.W.S. Trading, Thailand. Overall dimensions: 1.92 m height, 1.22 m width, and 0.80 m depth), vacuum dryer (VD53, Binder, Germany. Overall dimensions: 0.75 m height, 0.63 m width, and 0.55 m depth), and sun dried. The initial moisture content of the samples was 72 % (wet basis). Drying condition; hot air drying: temperature 45°C and 60°C, air flow 1.2-1.5 m/s, tray load 4.00-4.50 kg/m², vacuum drying: temperature 45°C, vacuum 300-400 mbar abs, and sun drying: the samples were dried under direct sunlight, started at 8:00 a.m. and continued till 5:00 p.m., temperature 38.2±4.5°C, the percent relative humidity of air 52 ± 6.2, air velocity 0.53 ± 0.22 m/s (these values were the average values, ±standards deviation). Tray loading in vacuum and sun drying were kept the same as in hot air drying. Moisture loss was recorded for determination of drying curves by scale balance at 60 min intervals for hot air and sun drying and 120 min intervals for vacuum drying. The samples were dried until equilibrium (no weight change) was reached.

4. Color analysis

Color analysis was carried out on wampee samples using a tristimulus colorimeter (Chromameter CR-200, Minolta, Osaka, Japan) to obtain the color values (CIE L^* , a^* and b^* values). L^* represents lightness, a^* represents greenness (-) to redness (+) while b^* represents blueness (-) to yellowness (+) values (Minolta, 1999). The changes in each individual color parameters were calculated as follows:

$$\Delta L^* = L^* - L_o^*; \quad \Delta a^* = a^* - a_o^*; \\ \Delta b^* = b^* - b_o^*$$

The subscript 'o' refers to the target value or the initial color parameters of each product at the beginning of the drying experiments. The total color difference (ΔE) was then determined using the following equation (Nsonzi and Ramaswamy,

1998):

$$\Delta E = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$$

At least five measurements were carried out on each sample.

5. Aroma analysis

Two samples of wampee fruit were used for aroma analysis, 500 g with fresh fruit and 200 g sundried fruit without soaking in brine and sugar. The Clevenger-type apparatus (Clevenger, 1928) hydro distillation extraction was used for extraction and concentration of volatiles for 6 h. 5 drops of silicone were added as antifoam. The volatiles oil was stored at -18°C prior to further analysis by the GC-MS (gas chromatography - mass spectrometer) analyses.

A GC-MS (Agilent 6890 and HP 5973 mass-selective detector, Agilent Technologies, Inc., Wilmington, DE 19808, USA) equipped with a fuse silica capillary column, HP-5MS, with 5%-Phenyl methyl polysiloxane as nonpolar stationary phase (30 m × 0.25 mm i.d. × 0.25 μm film thickness, Agilent Technologies) was utilized for analysis of volatiles obtained from distillation of wampee fruits. The samples were injected with a split ratio of 10:1. The injection port temperature was 250°C. The column temperature program started at 40°C upon injection. The temperature was increased at a rate of 3°C/min to 100°C, and then at a rate of 5°C/min to 230°C, and held there for 2 min. Purified helium gas at a flow rate of 1 ml/min was used as the GC carrier gas. The mass spectrometer was operated in the electron impact (EI) mode with an electron energy of 70 eV; ion source temperature, 230°C; quadrupole temperature, 150°C; mass range 35-400 m/z ; scan rate, 0.25 s/scan; EM voltage, 1423 V. the GC-MS transfer line was set to 280°C. Compounds were identified by matching their mass spectra with reference spectra in the Wiley 275 Mass Spectral Library (Revision C.00.00) and the NIST 98 Mass Spectral Library (Revision D.01.00/1.6d), both purchased from Agilent Technologies. Quantitative

analysis of each volatile component in percentage was performed by relative area normalization measurement.

6. Proximate analysis

Proximate analysis were determined by the methods of Association of Official Analytical Chemists (A.O.A.C., 1990)

7. Sensory analysis

Preference test on dried wampee products were done with 50 panel. All panelists were experienced with hedonic scale sensory test. The samples were randomized and coded with a three-digit number chosen from a table of random numbers. A 9-points hedonic scale (Meilgaard *et al.*, 1999) was used to assess the acceptance of various aspects (such as overall acceptance, appearance, aroma, flavor, and texture) of the products.

RESULTS AND DISCUSSION

In this study, the effect of drying method on drying rate of wampee was evaluated. It was found that visual appearance (attractive color) of vacuum-dried wampee sample was better than sun-dried and hot air-dried samples. When the experimental data of moisture content vs drying time were plotted, concave downward curves were obtained. These are typical of the drying curves obtained during drying. The results were generally in agreement with some literature studies on drying of various food products (Madamba *et al.*, 1996; Senadeera *et al.*, 2003; Yaldiz and Ertekin, 2001). Figure 3 shows the various drying methods. It could be seen that the increase in temperature from 45°C to 60°C hot air drying, reduced the time needed to reach equilibrium moisture content. This was according to kinetic theory, due to the increased energy of water molecules as temperature was increased. Hence, escaping of molecules became easier and faster from the medium.

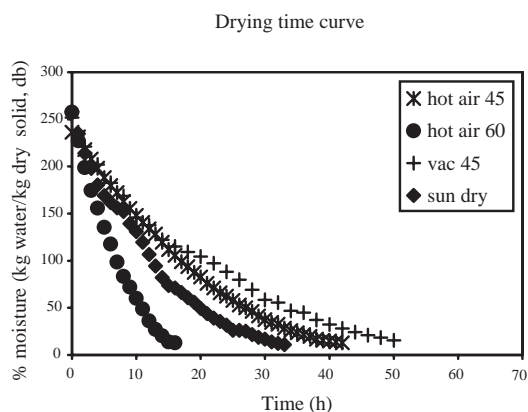


Figure 3 Drying time curves of different drying methods (sun dry, vacuum dry at 45°C, hot air dry at 45°C, and hot air dry at 60°C.)

Drying times in order to reach moisture content of about 14 % wet basis (0.16 kg water/kg dry solid) were 17, 32, 42, and 50 h by hot air drying at 60°C, sun drying, hot air drying at 45°C, and vacuum drying at 45°C, respectively. This moisture content was selected since it was the final moisture content of commercial dried wampee product. It has also been speculated (Karel *et al.*, 1994) that moisture contents at or below 15 % (wet basis) for most fruit is a rather safe indication that there is no microbial or mould growth and the reaction rate of a number of other deteriorative reactions (sugar crystallization, non-enzymatic browning, flavor deterioration, lipid oxidation, etc.) is significantly reduced.

The drying rate was determined from the slopes of the moisture content vs drying time curves, at each measurement point. The variation of the drying rates against moisture content are shown in Figure 4 for sun dry, vacuum dry at 45°C, hot air dry at 45°C, and hot air dry at 60°C. It was found that the drying rate decreased continuously with decreasing temperature. A constant rate period was observed in sun drying of the wampee samples. A comparison of the drying rates for the drying method obtained in this experiment were hot air drying at 60°C higher

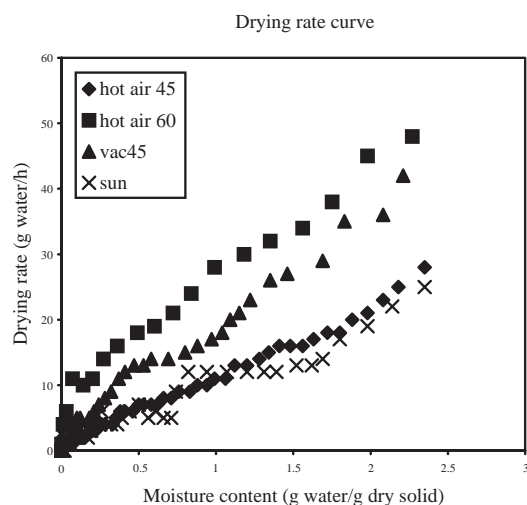


Figure 4 Drying rate curves for wampee at different drying methods (sun dry, vacuum dry at 45°C, hot air dry at 45°C, and hot air dry at 60°C.)

than vacuum drying at 45°C, hot air drying at 45°C and sun drying respectively.

Change in product color

Non-enzymatic reaction or the Maillard reaction, is often the limiting factor of dehydrated foods, particularly those with intermediate moisture content (Marty-Audouin *et al.*, 1999). The Maillard reaction occurs when foods are heat-treated. Parameters affected in the Maillard reaction are primarily temperature and the duration of heat treatment. The retention of color can be as a quality indicator to evaluate the extent of deterioration due to thermal processing (Avila and Silva, 1999). Changes of color and total change values are shown in Table 1.

Compared with the initial values of L^* a^* b^* (38.95, 5.6, 17.94) of wampee fresh fruit before drying, the ΔL^* values of hot air dry at 60°C, hot air dry at 45°C, sun dry, and vacuum dry at 45°C decreased considerably (-18.02, -12.07, -10.43, and -4.96, respectively). The respective net change in product color, ΔE were observed to be 21.49, 13.72, 12.75, and 6.61 for the same as ΔL^* values.

Table 1 Changes of color L^* a^* b^* and total change (ΔE) for wampee at different drying methods (sun dry, vacuum dry at 45°C, hot air dry at 45°C, and hot air dry at 60°C).

Samples	Color change			
	ΔL^*	Δa^*	Δb^*	ΔE
Sun dry	-10.43	4.06	-6.10	12.75
Vacuum 45°C	-4.96	3.83	-2.10	6.61
Hot air dry 45°C	-12.07	2.10	-6.16	13.72
Hot air dry 60°C	-18.02	0.25	-11.71	21.49

Vacuum drying at 45°C, with 6.61 ΔE gave the best color of dried wampee but took the longest drying time. Sun drying had 12.75 ΔE which was reasonably good color and also had reasonable time of drying (32 h).

Volatile compound analysis

The volatile oils from the samples of wampee fruit were extracted by hydrodistillation to obtain aroma compounds, and yields obtained were 0.11 ml/100g of fresh fruit and 0.50 ml/100g of sun dried fruit. Totally, 40 compounds were detected from both samples, 21 of these compounds were found in all extracts. The volatile oils consisted of at least 30 (fresh fruit) and 31 (sun dried fruit) components. The components of the oil examined are reported in Table 2. The fact was that majority of these components belong to the hydrocarbon fraction, with percentages of 95% in the fresh fruit and 94.98% in the sun dried fruit. Among the components of the hydrocarbon fraction, the predominant compounds were monoterpenes both in the fresh fruit and sun dried fruit. The main compounds were sabinene (66.73, 63.18 %), α -pinene (11.74, 9.57 %), and 1-phellandrene (7.25, 10.76 %). Only in the fresh fruit, cyclopropane, 3-carene, α -campholene aldehyde, cis-limonene oxide, pulegone, ascaridole, piperitone, limonyl alcohol, and ar-curcumen were found. In the sun dried fruit, dl-limonene, β -pinene, cyclopentane,

Table 2 Volatile compounds identified in the Wampee fresh fruit and sun dried.

Compounds	RT (Min)	%Relative area		Compounds	RT (Min)	%Relative area	
		Fresh frt.	Sundried			Fresh frt.	Sun dried
1. cyclopropane	7.620	0.02	-	21. pulegone	20.984	0.13	-
2. dl-limonene	9.029	-	0.03	22. 3-cyclohexen-1-ol	21.128	0.80	1.04
3. α -pinene	9.750	11.74	9.57	23. p-menth-2-en-1-ol	21.407	0.07	0.04
4. camphene	10.274	0.54	0.76	24. α -terpineol	21.835	1.18	1.79
5. β -pinene	11.520	-	0.10	25. phellandrene epoxide	22.378	0.12	0.12
6. myrcene	12.390	4.27	3.20	26. ascaridole	23.311	0.07	-
7. 1-phellandrene	12.939	7.25	10.76	27. carvota acetone	24.244	-	0.05
8. 3-carene	13.150	0.22	-	28. piperitone	24.518	0.08	-
9. 4-carene	13.511	1.72	3.58	29. phellandral	25.278	-	0.19
10. sabinene	14.400	66.73	63.18	30. acetic acid	25.591	0.13	0.17
11. 1,4-cyclohexadiene	15.506	0.19	0.32	31. limonol alcohol	27.076	0.07	-
12. β -fenchene	16.112	0.04	0.03	32. trans-ocimene	27.380	-	0.17
13. α -campholene aldehyde	17.295	0.06	-	33. 3-cyanomethy thiophene	28.562	0.02	0.17
14. linalool	17.584	0.38	0.24	34. 1H-3a, 7-methanoazulene	29.606	-	0.19
15. fenchol	18.084	0.18	0.13	35. isosativene	29.851	0.13	0.19
16. cis-limonene oxide	19.041	0.10	-	36. tran- β -farnesene	30.924	-	0.05
17. γ -terpinene	19.373	1.60	2.49	37. benzene	31.640	0.10	0.14
18. α -fenchene	19.676	0.17	0.18	38. ar-curcumene	31.650	0.03	-
19. isoborneol	20.590	0.05	0.08	39. widdrene	36.329	-	0.04
20. cyclopentane	20.700	-	0.11	40. γ -curcumene	36.329	-	0.04
% Identified						98.19	99.15

RT = Retention time

- = not found

carvota acetone, phellandral, tran-ocimene, 1H,3a,7-methanoazulene, tran- β -farnesene, widdrene, and γ -curcumene were found.

It should be noted that sabinene was extremely abundant in both oils examined, 1-phellandrene was more abundant in sun dried fruit oil than in fresh fruit oil, and α -pinene was more abundant in fresh fruit oil than in sun dried fruit oil.

Proximate analysis

The results of the chemical analysis performed on fresh and sun dried fruit of wampee are summarized in Table 3 The measure pH value of the fruit juice was 3.3, which corresponds with the high concentration of fruit acids and total soluble solid (TSS) was 17.5 °brix.

Sensory analysis

Sensory analysis scores of dried wampee fruits are shows in Table 4. Wampee sample from

sun drying was rated significantly higher than hot air drying and vacuum drying on aroma, flavor, texture and overall acceptance, except for vacuum drying in color attribute scored 7.6 or close to 'Like very much' higher than sun drying. This was primarily because it had specifical aroma of sun dry.

Table 3 Proximate composition of fresh and dried wampee fruits.

Components (% by wt)	Fresh fruits	Sun dried fruits
Water	71.97	16.34
Carbohydrate (by difference)	18.64	58.38
Fat	0.33	0.39
Fiber	4.58	8.42
Protein	1.88	7.56
Ash	2.6	8.91

Table 4 Mean values for sensory evaluation of dried wampees from different drying methods (sun dried, hot air dried at 45°C, hot air dried at 60°C, and vacuum dried at 45°C).

Attributes	Sun dried	Hot air dried 45°C	Hot air dried 60°C	Vacuum dried 45°C
Color	6.8 ^b	6.9 ^b	5.4 ^c	7.6 ^a
Aroma	6.7 ^a	5.9 ^b	6.3 ^{ab}	5.9 ^b
Flavor	7.7 ^a	7.0 ^b	6.2 ^c	5.5 ^d
Texture	7.2 ^a	6.8 ^a	5.6 ^b	5.6 ^b
Overall acceptance	7.1 ^a	6.4 ^b	5.8 ^c	5.9 ^c

Means in the same horizontal row with different superscripts are significantly different ($p < 0.05$).

CONCLUSION

The study of wampee drying methods revealed the following conclusion: the drying times to reach 14 % (wb) moisture content were 17, 32, 42, and 50 h by hot air drying at 60°C, sun drying, hot air drying at 45°C, and vacuum drying at 45°C, respectively. The total change in product color, ΔE were observed to be 21.49, 13.72, 12.75, and 6.61 by hot air drying at 60°C, hot air drying at 45°C, sun drying, and vacuum drying at 45°C, respectively. Analysis by GC-MS of the volatile oils obtained from fresh fruit and sun dried fruit revealed 40 components. The major constituents were found to be sabinene, α -pinene, and 1-phellandrene.

ACKNOWLEDGEMENTS

We are grateful to National Pingtung University of Science and Technology (NPUST), Taiwan R.O.C., and the Graduate School, Kasetsart University for providing the equipment, and research funds for this research.

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