Drying of feverfew (*Tanacetum parthenium L.*)

H.M. Tanko[1], D.J.Carrier[2]*, S. Sokhansanj[3] and T.G. Crowe[4]

*[1]Bregma Materials Solutions Inc., 114 – 116 Research Drive, Saskatoon, Saskatchewan S7N 3R3, Canada; [2]Department of Biological and Agricultural Engineering, 203 Engineering Hall, University of Arkansas, Fayetteville, Arkansas 72701, USA; [3]Department of Chemical and Biological Engineering, University of British Columbia, 2216 Main Mall, Vancouver, British Columbia V6T 1Z4, Canada; and [4]Department of Agricultural and Bioresource Engineering, University of Saskatchewan, Saskatoon, Saskatchewan S7N 5A9, Canada. *Email: carrier@uark.edu*

Tanko, H.M., Carrier, D.J., Sokhansanj, S. and Crowe, T.G. 2005. **Drying of feverfew (*Tanacetum parthenium L.*)** Canadian Biosystems Engineering/Le génie des biosystèmes au Canada **47**: 3.57 - 3.61. Feverfew (*Tanacetum parthenium L.*) is currently used in the treatment of migraine in North America. The sesquiterpene lactone, parthenolide, could be one of the active components. This plant is now being cultivated as a medicinal plant crop and this is necessitating post-harvesting protocol development. Thin-layer drying studies of the leaves were conducted at 30.1, 44.6, and 58.8°C. As expected, the drying time decreased with increased drying temperature. Parameters for the Page and Lewis thin-layer drying equations were determined. Fit of the experimental data was best with Page's equation. Values for the drying parameter, *k*, were 0.0064 ± 0.0014, 0.0108 ± 0.0016, and 0.0130 ± 0.0018 min^{-n} for drying temperatures at 30.1, 44.6, and 58.8°C, respectively. The activation energy was calculated as 19.86 kJ K^{-1} mol^{-1}, using an Arrhenius-type relationship. **Keywords** drying, feverfew, herbal plants, leaves, medicinal, *Tanacetum parthenium*, thin layer drying.

En Amérique du Nord, *Tanacetum parthenium L.* est une plante médicinale surtout utilisée pour soulager la migraine. Il est possible que la parthenolide, soit une des composantes responsable pour son activité. Puisque, *T. parthenium* est cultivée en grande quantité, des protocoles adressant ses pratiques de sèchage sont nécessaires. Le sèchage en couche mince de *T. parthenium* a été essayé à des températures de 30.1, 44.6 et 58.8°C. Au cours du sèchage en couche mince, le temps nécessaire pour le sèchage était inversement proportionnel à la température. Les paramètres de deux équations qui décrivent le sèchage en couche mince, soit les équations de Page et de Lewis, furent déterminés. L' équation de Page a mieux décrit le sèchage en couche mince de *T. parthenium*.

INTRODUCTION

Feverfew (*Tanacetum parthenium* L.) probably originated in the Balkan Peninsula and was introduced into the British Isles, where it grows both wild and in cultivation, and it is now found in North America, Europe, North Africa, China, Japan, and Australia (Barl et al. 1996). Feverfew is a medicinal plant, which has been used in the treatment of many diseases such as psoriasis, menstrual problems, insect bites, toothache, asthma, and rheumatism since ancient times (Knight 1995). Feverfew is also popular for the treatment of migraine following a successful study and clinical test (Johnson et al. 1985; Murphy et al. 1988). It is believed that parthenolide, a sesquiterpene lactone, is the active component in the treatment of migraine (Awang 1989; Groenewegen and Heptinstall 1990), but other ingredients in the plant may also play a role (De Weerdt et al. 1996). These encouraging results have stimulated interest in both growers and researchers leading, to studies on chemical characterization and agronomy. Production of feverfew has increased over the years and it is now ranked among the top twenty selling herbs in North America (Fitzpatrick 2000), therefore creating competition among suppliers.

An important factor in the delivery of quality herbs to the consumer is the control of its moisture content. Producers must properly and efficiently harvest, dry, and store feverfew for commercial purposes. Feverfew, like many other herbs, is dried mostly in ambient air (Hendriks et al. 1997) for a period up to 14 days. This is believed to prevent or reduce the degradation of the active ingredient, parthenolide. However, Tanko et al. (2003) reported that drying temperature within the range of 30 to 60°C did not result in a decrease of the parthenolide concentration of feverfew leaves.

Thin-layer drying data and equations are required for the design and analysis of drying systems. Feverfew is a leafy crop, similar to alfalfa. Thin-layer drying studies conducted at 60°C showed that the drying rates were affected by alfalfa's initial moisture content (Patil et al. 1992). Sokhansanj and Patil (1996) recommended the use of Page's equation to describe the thin layer drying of alfalfa over Lewis's equation (ASAE 2001b). The results of Hansen et al. (1993) from thin-layer drying studies of Taxus clippings, needles and stems showed that the drying rates increased 28, 15, and 3 times as drying temperatures increased from 30 to 60°C, 40 to 60°C, and 50 to 60°C, respectively. No published studies on drying rates for feverfew are available. Most of the published thin-layer drying data are for grains and other agricultural crops with very little on herbs and other foliage (ASAE 2001a). The aim of this study is to develop drying rate data for feverfew leaves.

MATERIALS and METHODS

The aerial part of feverfew (*Tanacetum parthenium* L.) plant consists of flowers, leaves, and stem. Characteristics of the aerial parts differ from one another; hence, it was advisable to dry each part separately. This study focused only on leaves because of their demonstrated efficacy in terms of treatment of migraine (Awang 1998).

Feverfew plants grown on an irrigated field near Outlook, Saskatchewan were harvested at full-bloom. The manually cut plants were kept in black polyethylene bags and transferred to a cooler before transport to the laboratory in Saskatoon, Saskatchewan where the plants were kept in a 4°C refrigerator. To conduct an experiment, a random sample of plants was removed from a bag. Leaves were separated from the plants

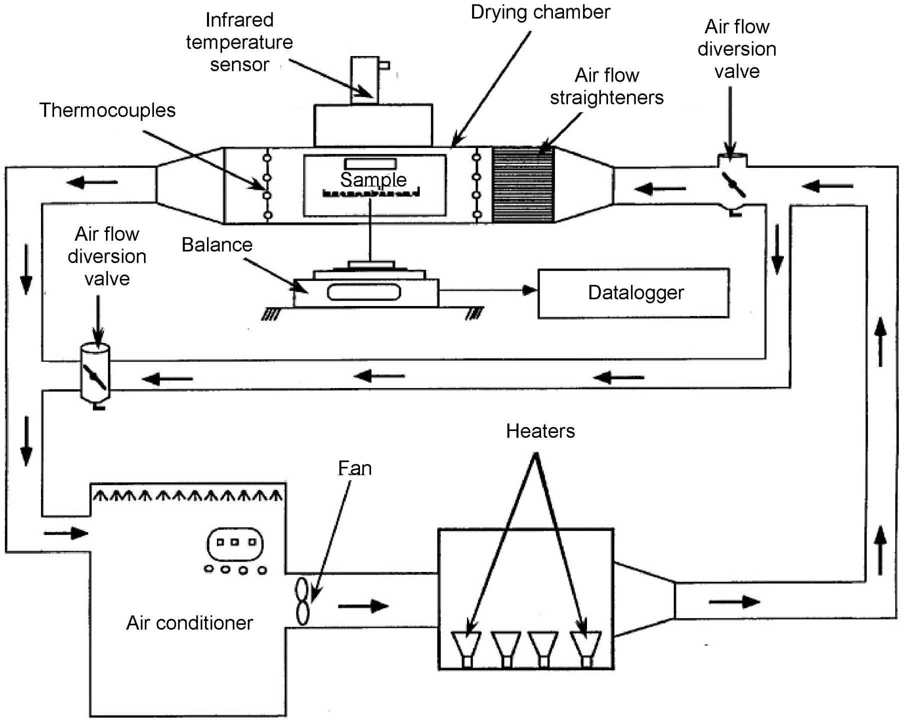

Fig. 1. Schematic diagram of thin-layer drying equipment.

making sure no foreign matter or any other part of the plant was mixed with the leaves. This formed a sample for a drying experiment. From preliminary measurements, the major axis of the leaves ranged from 19 to 42 mm and minor axis ranged from 13 to 25 mm. Initial moisture content of a sample was determined using the air oven method by drying at 103°C for 24 h (ASAE standard S358.2; ASAE 2001a).

Figure 1 shows a schematic diagram of the thin-layer drying equipment. The dryer consisted of a fan that blew atmospheric air through ducts fitted with valves, an air conditioning unit, heaters, and a drying chamber with a sample holder resting on a digital electronic balance. The mass of the sample was measured using the electronic balance. Air relative humidity was determined using a wet and dry psychrometer constructed from T-type thermocouples and cotton shoelace as a wick. The air relative humidity was not controlled. A grid of five thermocouples (one at each of the four corners and one in the middle) placed upstream, immediately after the air flow atraighteners, and downstream, immediately after the sample, measured drying-air temperature. An infrared temperature sensor was used to measure the surface temperature of the samples during each drying experiment, while a pitot tube was used to measure air velocity before flowing through the sample. The logged data were stored in a personal computer.

The drying experiment was conducted at three different temperatures of 30, 45, and 60°C and replicated six times at each temperature. The first five tests were made to develop a drying rate equation. The sixth test was used to validate the drying equation. The mass of the sample holder on which the sample was spread was tared before spreading the sample on it. This allowed the actual mass of the sample to be recorded during the drying process. The leaves that constituted a sample were spread on the sample holder. A sample was 300 x 200 mm wide and approximately 20 mm deep to form a thin layer.

Samples removed from the refrigerator were allowed to equilibrate at room temperature for 30 min before drying. The initial mass of a sample was approximately 60 g. To ensure stable air conditions during the experiments, the equipment was set at the desired temperature and started on average for 30 min to attain stability before placing samples in the drying unit for data collection, in accordance with ASAE Standards S448 (ASAE 2001b). The mass of the drying sample was recorded every 0.25 min for the first 10 min of drying, every 1 min for the next 50 min, every 15 min for the next 5 h, and every 1 h for the rest of the drying period. Drying was terminated when the change in mass between two successive readings was within 0.01g. At this stage, it was assumed that equilibrium moisture content had been reached.

Lewis's equation (Eq. 1) and Page's equation (Eq. 2) are recommended for describing thin-layer drying of agricultural crops (ASAE 2001b):

$$\frac{M - M_e}{M_0 - M_e} = \exp(-kt) \tag{1}$$

$$\frac{M - M_e}{M_0 - M_e} = \exp(-kt^n) \tag{2}$$

where:
M = moisture content on a dry basis (db),
M_e = equilibrium moisture content,
M_o = initial moisture content of sample,
t = time, and
k, n = drying constants.

Thin-layer Eqs. 1 and 2 were transformed to linear form by logarithmic transformation. The linear equations were fitted to the data using the LINEST function in Microsoft Excel.

RESULTS and DISCUSSION

It was desired to test drying at 30, 45, and 60°C; however, the experiments were actually conducted at 30.1 ± 1.0, 44.6 ± 1.6, and 58.8 ± 2.9°C. The recorded relative humidity of the drying air ranged from 37 to 68%, 16 to 41%, and 5 to 26% during drying experiments conducted at 30.1, 44.6, and 58.8°C, respectively. The downstream temperatures recorded during each test were 2 to 5°C lower than those of upstream due to heat loss and evaporative cooling. The air velocity recorded ranged from 0.57 to 0.82 m/s during the thin-layer drying experiments. Figure 2 shows a plot of typical moisture content data versus time for the three drying temperatures. The total drying times to

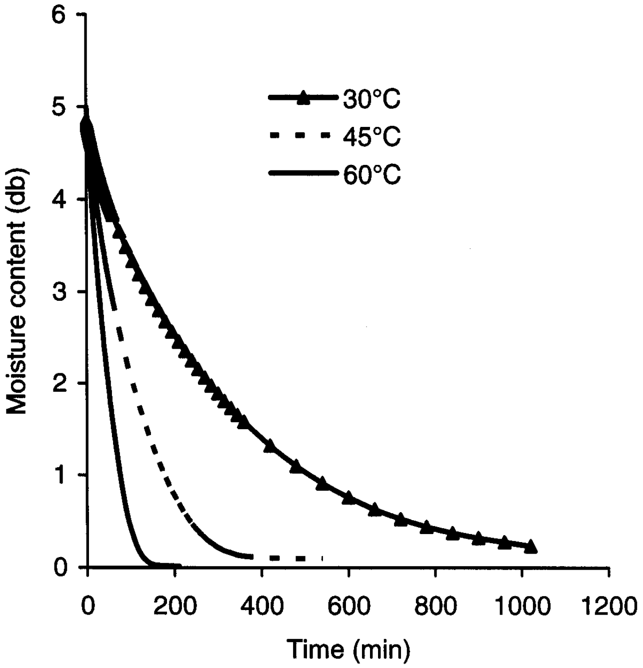

Fig. 2. Moisture content of feverfew leaves as a function of drying time for the three drying temperatures.

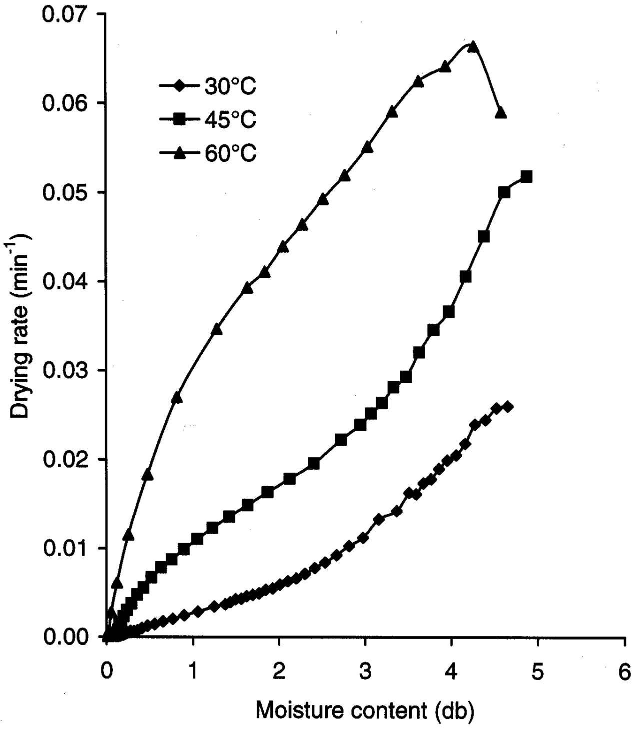

Fig. 3. Drying rate as a function of moisture content at the three different drying temperatures.

reach equilibrium moisture content at temperatures of 30.1, 44.6, and 58.8°C were 2309, 930, and 476 min, respectively. The drying time decreased by about a factor of 2 when using air at 58.8°C as compared to 44.6°C. The large decrease in drying time observed with an increased drying temperature could be attributed not only to an increase in vapor pressure deficit, but also to melting of natural waxes on the leaves. Thaine (1969) studied the effect of temperature on the drying of grass, and showed that the removal of cuticular waxes increased the drying rate. Feverfew's parthenolide content did not increase when dried at temperatures lower than 60°C (Tanko et al. 2003). Thus, drying time of feverfew could be reduced by drying at temperatures near to 60°C.

Table 1 shows the mean initial and equilibrium moisture content and the mean drying time for the samples. On average, the initial moisture content of feverfew leaves at full bloom (100% flowering) was 82.7% wet basis (wb). The variation in initial moisture content of sample leaves was small. The final equilibrium moisture content showed considerable variation with each drying temperature. The large variations in equilibrium moisture content might have been caused by variability in relative humidity. The variability in drying time to reach 10% moisture content was not as great as the variability in drying time to reach equilibrium moisture content at 44.6 and 58.8°C.

Figure 3 shows the drying rate of feverfew leaves plotted as a function of moisture content for the three drying temperatures. In spite of the high initial moisture content of the leaves, no constant drying period was observed in any of the three drying temperature curves. However, two distinct drying periods, namely initial transitional warm-up and falling rate periods, were detected on the 58.8°C drying temperature curve. The drying rate curve of the 58.8°C sample was convex whereas the curve for the 30.1°C sample was concave. The curve for the 44.6°C sample was concave at high moisture content but became convex at low moisture content. It is postulated that at 58.8°C and at a moisture content ranging from 0.1 to 0.2 decimal db, the internal structure of leaves could shrink to a degree that blocks the movement of moisture to the outside. The absence of the constant rate period also suggests that diffusive drying took place during the entire drying period.

Table 1. Initial and equilibrium moisture contents and drying times for feverfew leaves dried at 30.1, 44.6 and 58.8°C. Means are for five experiments at each temperature.

Drying temperature (°C)	Mean initial moisture content (% wb)	Mean equilibrium moisture content (% wb)	Mean time to reach equilibrium moisture content (min)	Mean time to reach 10% moisture content (min)
30.1	82.9 ± 0.5	10.4 ± 2.3	2309 ± 301	1660 ± 458
44.6	82.9 ± 0.6	4.1 ± 3.3	930 ± 330	358 ± 27
58.8	82.7 ± 0.7	3.5 ± 1.7	476 ± 154	125 ± 4

Table 2. Analysis of thin-layer drying experiments using one-parameter (Lewis, Eq. 1) and two-parameter (Page, Eq. 2) exponential equations. Means are for five experiments at each temperature.

Drying temperature (°C)	Equation	k (min^{-n})	n*	R^2	SEE
30.1	One-parameter	0.0037 ± 0.0002	-	1.00	0.0034
	Two-parameter	0.0064 ± 0.0014	0.8920 ± 0.0248	0.95	0.0019
44.6	One-parameter	0.0113 ± 0.0008	-	1.00	0.0021
	Two-parameter	0.0108 ± 0.0016	0.9618 ± 0.0301	0.95	0.0015
58.8	One-parameter	0.0293 ± 0.0050	-	1.00	0.0133
	Two-parameter	0.0130 ± 0.0018	1.1093 ± 0.0294	0.96	0.0032

* n = 1 for the one-parameter model

Table 2 lists the averages of *k* and *n* values for the first five drying experiments at each of the drying temperatures. As expected, the drying constants, *k* and *n*, increased with higher drying air temperatures. Misra and Brooker (1980) reported that air temperature and initial moisture content most significantly affected parameter *k*, while the relative humidity and moisture content affected parameter *n* in thin-layer drying of corn. Henderson and Pabis (1962) and Hutchinson and Otten (1983) reported that thin-layer drying of grains does not depend on air velocity when above 0.2 m/s. Because air velocity in this work ranged from 0.57 to 0.82 m/s, it is most likely that this parameter did not affect thin-layer drying of feverfew. The standard error of estimation (SEE) was obtained when the predicted moisture ratios were compared to that of the sixth experiment (moisture ratio obtained from sixth experimental data). Smaller SEE values were obtained while using the Page (two-parameter exponential equation, Eq. 2) than with the Lewis (one-parameter exponential, Eq. 1) equation. The use of Page's equation also resulted in smaller SEE values while drying alfalfa (Patil 1995; Sokhansanj and Patil 1996). ASAE Standard S448 (ASAE 2001b) recommends Page's equation for describing thin-layer drying of agricultural crops. Thus, thin-layer drying of feverfew can be modelled with Page's equation.

By plotting the parameter, *k*, as a function of drying temperature (not shown) in a Arrhenius-type relationship as in Henderson and Pabis (1961), the activation energy for feverfew was calculated as 19.86 kJ K^{-1} mol^{-1}. The calculated activation energy for feverfew was lower than 26.76 kJ K^{-1} mol^{-1}, which is the activation energy calculated for alfalfa (Sokhansanj and Patil 1996). The activation energy is an indication of the amount of energy necessary to remove moisture from a solid matrix. The higher activation energy value calculated for alfalfa could be attributed to the lower initial moisture content of alfalfa leaves used in the study.

CONCLUSIONS

As expected, drying time decreased with increased drying temperature. In spite of high initial moisture content of the foliage, no constant drying period was observed in any of the three drying temperature curves. Page's equation fitted the thin-layer drying data of feverfew better than Lewis's equation. The activation energy was calculated as 19.86 kJ K^{-1} mol^{-1}.

ACKNOWLEDGEMENT

This project was funded by a research program supported by Agri-Food Innovation Fund (AFIF), Natural Sciences and Engineering Research Council of Canada (NSERC) and the Agriculture Development Fund (ADF). The Canada-Saskatchewan Irrigation Diversification Center (CSIDC) at Outlook provided feverfew samples. The assistance provided by Bill Crerar, Research Engineer, and Wayne Morley, Electronic Technologist, in the Department of Agricultural and Bioresource Engineering, University of Saskatchewan is gratefully acknowledged.

REFERENCES

ASAE. 2001a. Standard S358.2 - Moisture measurement-forage. In *ASAE Standards 2001*, 45th edition, 591. St. Joseph, MI: ASABE.

ASAE. 2001b. Standard S448 - Thin-layer drying of grains and crops. In *ASAE Standards 2001*, 45th edition, 605 - 607. St. Joseph, MI: ASABE.

Awang, D.V.C. 1989. Feverfew. *Canadian Pharmaceutical Journal* 122: 266-270.

Awang, D.V.C. 1998. Prescribing therapeutic feverfew (*Tanacetum parthenium* (L.) Schultz Bip., Syn. *Chrysanthmum parthenium* (L.) Bernh). *Integrative Medicine* 1: 11-13.

Barl, B., D. Loewen and E. Svendsen. 1996. Saskatchewan Herb Database, 122-127. Department of Plant Science, University of Saskatchewan, 51 Campus Drive, Saskatoon, SK.

De Weerdt, C.J., H.P.R. Bootsma and H. Hendriks. 1996. Herbal medicines in migraine prevention: Randomized double-blind placebo-controlled crossover trial of a feverfew preparation. *Phytomedicine* 3: 225-230.

Fitzpatrick, K.C. 2000. Nutraceuticals – a booming industry. In *Herbs 2000 - Proceedings of the International Herb Conference*, 97-103. Saskatoon, SK: International Herb Association and Canadian Herb Society.

Groenewegen, W.A. and S. Heptinstall. 1990. Comparison of the effects of an extract of feverfew and parthenolide on human platelet activity in vitro. *Journal Pharmacy and Pharmacology* l42: 533-557.

Hansen, R.C., H.M. Keener and H.N. Elsohly. 1993. Thin-layer drying of cultivated taxus clippings. *Transactions of the ASAE* 36: 1873-1877.

Henderson, S.M. and S. Pabis. 1961. Grain drying theory I-temperature effect on drying coefficient. *Journal of Agricultural Engineering Research* 6: 169-174.

Henderson, S.M. and S. Pabis. 1962. Grain drying IV- The effect of air flow rate on the drying index. *Journal of Agricultural Engineering Research* 7: 85-89.

Hendriks, H., Y.A. Wildeboer, G. Engels, R. Bos and H.J Woerdenbag. 1997. The content of parthenolide and its yield per plant during the growth of *Tanacetum parthenium. Planta Medica* 63: 356-359.

Hutchinson, D. and L. Otten. 1983. Thin-layer drying of soya beans and white beans. *Journal of Food Technology* 18: 507-522.

Johnson, E.S., N.P. Kadam, D.M. Hylands and P.J. Hylands. 1985. Efficacy of feverfew as prophylactic treatment of migraine. *British Medicinal Journal* 291: 569-573.

Knight, W.D. 1995. Feverfew, chemistry and biological activity. *Natural Product Reports* 12: 271-276.

Misra, M.K. and D.B. Brooker. 1980. Thin-layer drying and rewetting of shelled yellow corn. *Transactions of the ASAE* 3: 1254-1260.

Murphy, J.J., S. Heptinstall and J.R.A. Mitchell. 1988. Randomized double-blind placebo-controlled trial of feverfew in migraine prevention. *Lancet* ii: 189-192.

Patil, R.T. 1995. Kinetics of dehydration and quality changes of alfalfa. Unpublished PhD. thesis. Department of Agricultural and Bioresource Engineering, University of Saskatchewan, Saskatoon, SK.

Patil, R.T., S. Sokhansanj, E.A. Arinze and G.J. Schoenau. 1992. Thin-layer drying of components of fresh alfalfa. *Canadian Agricultural Engineering* 34: 343-346.

Sokhansanj, S. and R.T. Patil. 1996. Kinetics of dehydration of green alfalfa. *Drying Technology* 14: 1197-1234.

Tanko, H.M., D.J. Carrier, S. Sokhansanj and T.G. Crowe. 2003. Effects of drying temperature and storage on parthenolide concentration of feverfew (*Tanacetum parthenium L.*) leaves. *Journal of Nutraceuticals, Functional and Medicinal Foods* 4: 27-37.

Thaine, R. 1969. The effect of temperature on the drying of grass. *Journal of Agricultural Engineering Research* 16: 213-222.