J. Ginseng Res.
Vol. 27, No. 3, 141-145(2003)

High Temperature Drying of North American Ginseng for Management Decision Making

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(Received March 27, 2003, Accepted July 22, 2003)

Abstract : The multi-year production cycle for ginseng can be rapidly depreciated by inferior post-harvest activities. This research examines the character of high temperature drying regimes for North American ginseng root to assist management decision making. The objective is a very rapid drying regime, that will not result in physical or chemical damage to the root and that would not alter the actual dry root weight. Research is presented using drying temperatures of 55, 70 and 105°C. Temperatures above these rapidly cause substantive physical damage to the root samples and seriously compromise the dry root values determined. Temperatures below these behaved quite similar to actual dryer regimes (approximately 38°C). Laboratory results indicate that there are differences between the three temperature regimes tested. Careful usage of the 70°C regime, over a period of two to three days in a convection drying oven, has distinct merit.

Key words : North American ginseng, drying, management decision making

INTRODUCTION

The drying of North American ginseng (*Panax quinquefolius* L.) borrows from two distinct spheres: the science of dehydration, and the art of product quality criterion determination for an agricultural commodity that is predominately sold in the Greater China marketplace. It is also well recognized that the multi-year production cycle for North American ginseng and its careful management can be rapidly depreciated by inferior harvest and post-harvest activities. In these times of marketplace uncertainty, these issues create significant challenges. A key aspect is the actual, absolute dry weight of North American ginseng root. This has importance for cold storage management (through the impact of total root mass loss in cold storage over long time scales), the washing environment (roots being washed may rehydrate if left in the water bath too long), and the thermal and humidity regimes maintained in dryer environments to achieve a high quality dried product. In the latter case, the root is dried using specific objective and subjective criterion, and some moisture is left in the dried product. However, if the moisture amount is significant, root deterioration may occur (through mold, etc.). If over-dried, the quality is less and, also, the total economic return to the producer is reduced. A central issue is that the root has a wide range in the ratio of fresh weight to dry weight. In fact, a wide range in shape, size, density and other factors has a significant impact on the moisture content of the root.

This research addresses the aforementioned issues through the study of a high temperature drying regime for North American ginseng root for management purposes. The objective is to have a rapid drying regime that will not result in physical or chemical damage to the root and that would not alter the actual dry root weight. It is recognized from the outset that the drying technique would not be for commercial production; rather, it would be used to determine dry weight to better manage and optimize post-harvest activities. Particular emphasis is given to two topics. First, the role of root rehydration is considered, as the use of water submersion during washing may result in root moisture increase. Second, three higher temperature drying regimes (55, 70 and 105°C) are examined.

MATERIALS AND METHODS

Two principal studies were undertaken: ginseng root

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rehydration arising from submersion; and, the character of higher temperature ginseng root drying.

Twenty-seven ginseng roots were employed in the study of root rehydration. These roots were fresh harvested in the arid interior of British Columbia, Canada. These were then transferred to Simon Fraser University for analysis purposes. Prior to water bath submersion, all roots were weighed in their fresh state. A water bath at room temperature (approximately 20°C) was used for submersion. All roots were submerged for 4 hours, after which, roots were reweighed. This allowed the calculation of percentage weight gain (fresh weight basis).

In the study of the drying regimes (55, 70 and 105°C), a total of 27 roots were employed. All of the roots were selected to provide a range in size (represented by weight) and be of a cylinder/tapered form, so as best as possible to standardize geometric characteristics. Three small, medium and large roots were included in each group dried at the various temperatures. All roots were fresh harvested in the arid interior of British Columbia, Canada, and then transferred to Simon Fraser University for analysis purposes. Prior to drying, all roots were weighed in their fresh state and then submersed in a water bath at room temperature (approximately 20°C) for 4 hours to ensure that all roots were not subject to moisture depletion. Roots were weighed at the beginning of the high temperature drying period and for nine intervals after that. Drying was done at temperatures of 55, 70 and 105°C in a forced air convection oven.

RESULTS AND DISCUSSION

The results and discussion are presented in two sections. The first addresses ginseng root rehydration. The second, and principal contribution, examines the nature and character of the three high temperature drying regimes on ginseng roots.

1. Rehydration of North American ginseng roots

After root submersion for 4 hours, root rehydration occurs and is both substantive and variable. Fig. 1 demonstrates the relationship found between moisture rehydration and initial root weight. Although there is considerable scatter (maximum of 13.4% and minimum of 2.9%), there is the suggestion of a non-linear relationship. In general, the lower the initial weight of the root sample, the higher the percentage increase in weight due to moisture re-entry into the root.

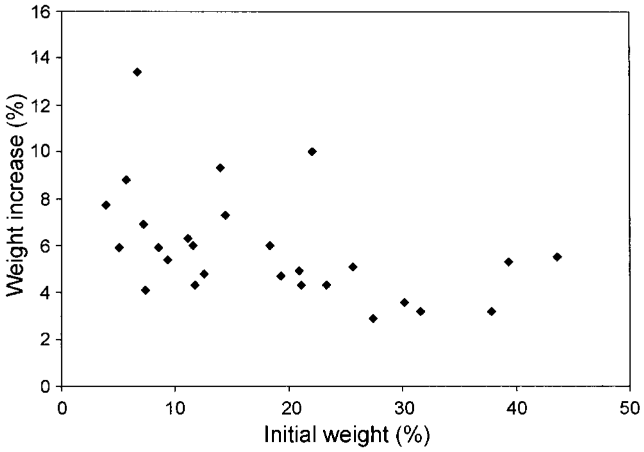

Fig. 1. The relationship between percentage root weight increase and initial weight of roots after submersion in a water bath for 4 hours. For the 27 observations, the mean is 5.89% and the standard deviation is 2.36%. The line defining the non-linear relationship is given by the power function $y=12.073X^{0.291}$, with r=0.536.

The wide scatter in the data relationship is not unexpected. In the field, during the autumn pre-harvest conditions, there are a number of physiochemical changes occurring in the roots. Hence, a range in actual moisture contents and rehydration capacity is not unexpected. The nature of the non-linear relationship is also not unexpected. In fact, it provides a graphical summary of the relationship between the surface area of the root and the root volume. Consider a root cross-section that is circular. For small diameter roots (herein represented by roots of low initial weight), the ratio of circumference ($2\pi r$) to area (πr^2) decreases as diameter increases. Hence, for small diameter roots, the larger circumference permits a greater surface area per unit volume for moisture uptake. As diameter increases, cross-sectional area(and also root volume) increases faster than circumference(surface area) increases. This results in a relative decrease in the effective surface area of the root. With all else constant, the potential rehydration rates will be less as diameter increases.

These rehydration research results have practical implications for producers. If root is harvested and left in the outside environment, rewetting by rain may result in moisture gain. This will increase the resultant drying time. If water baths are employed for washing, extensive periods may result in moisture gain. Again, this would lead to increased drying time. Further, it is apparent that there is large scatter in the relationship between root initial weight and rehydration. Further work is needed to establish the season-to-season variability and the responsible factors.

Although not explicitly studied, there is some suggestion that variations in late season root moisture status may play some role in the quality of dried ginseng, particularly in the development of desired latitudinal surface ring patterns and the non-desired longitudinal surface line patterns.

2. Drying of North American ginseng roots at 55, 70 and 105°C

The rehydrated roots were dried at 55, 70 and 105°C. These temperatures were selected as representative of the range often employed in plant tissue and soil drying analysis. The important features to be considered are the shortness of the duration of the drying period and the absence of physiochemical damage to the roots.

Fig. 2a presents the results for 9 roots dried at 55°C. From the figure, it is apparent that three clusters of drying trends occur. The fastest drying is found for roots of lighter weight(initial weights of 4.2 to 7.7 g), which have small diameters and, hence, high circumference to cross-sectional area ratios. The next fastest are 2 roots (initial weights of 12.2 and 13.1 g) of intermediate weight. The slowest are roots of larger weight (initial weights of 15.2 to 41.4 g) and these have the lowest circumference to cross-sectional area ratios. From the data displayed, two aspects are evident. The first is that for dry weight evaluation, three days of drying would be appropriate. At shorter time periods, there would be a small chance that the largest roots may not be fully dried. Also, it is apparent that the dry matter content of the individual ginseng roots is not a constant, but a variable (ranging from a minimum of 29.9% to a maximum of 36.8% of fresh weight, with a mean of 32.8%). The inherent problem for the management of drying regimes is clearly apparent as also is the need for adequate sampling to characterize the root in commercial drying systems.

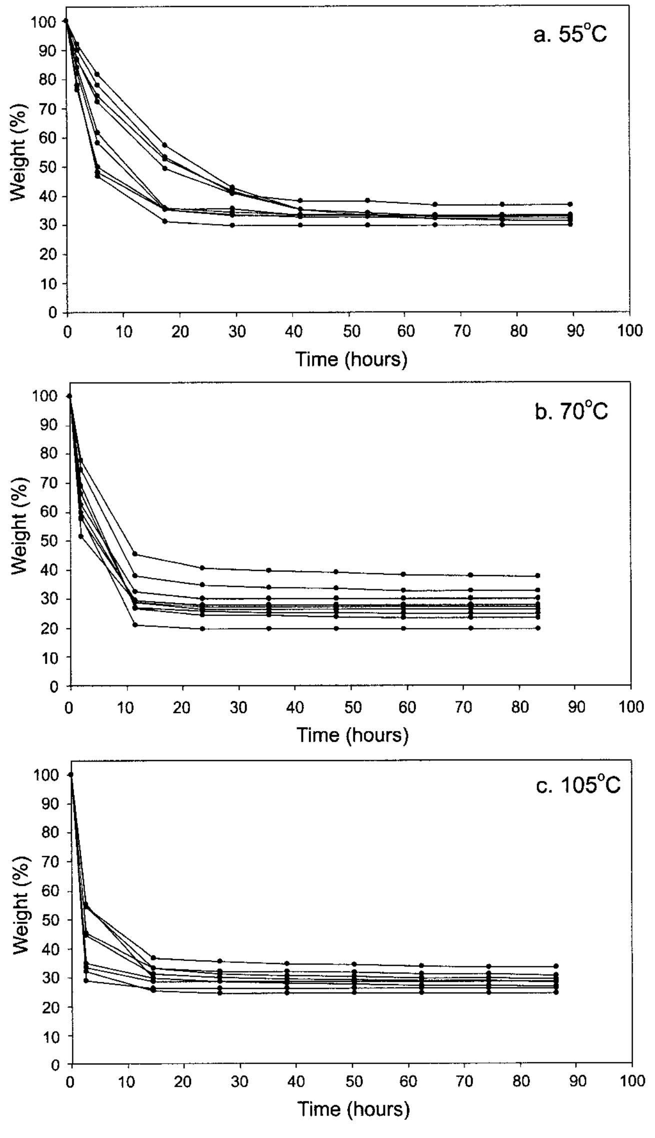

Fig. 2. The drying trend of ginseng roots at 55, 70 and 105°C.

Fig. 2b presents the results for 9 roots dried at 70°C. From the figure, it is apparent that the trends are similar in general form to those presented in Fig. 2a. Generally the largest roots dried slower and had higher final dry weights. It is also apparent that the dry matter content is not a constant, but again a variable (ranging from a minimum of 19.6% to a maximum of 37.7% of fresh weight, with a mean of 27.9%). The inherent problem for the management of drying regimes is again apparent.

Fig. 2c presents the results for 9 roots dried at 105°C. From the figure, like the data for the 55°C drying, it is apparent that three clusters of drying trends occur. The fastest drying is found for 4 roots of lighter weight. These have small diameters and, hence, high circumference to cross-sectional area ratios. The next fastest are 2 roots of intermediate weight. The slowest are roots of larger weight and these have the lowest circumference to cross-sectional area ratios. From the data displayed, two aspects are evident. The first is that dry weights determined after two days would be satisfactory. Also, it is apparent that the dry matter content is not a constant, but again a variable (ranging from a minimum of 24.6% to a maximum of 33.5% of dry weight, with a mean of 28.5%). Further, at a temperature of 105°C, some minor damage to the roots was visible and at longer durations, the potential for loss of dry matter is high.

It is to be noted, that for the three groups of roots dried at different temperatures, statistical analysis shows that the roots dried at 55°C had significantly higher(calculated) dry matter content than roots dried at 70 or 105°C. However, there were no significant differences in fresh matter contents (Tukey-Kramer α=0.05). The higher dry matter content at 55°C may be a result of incomplete drying of the root in the oven and which would result in a higher calculated dry matter content. This observation is further supported by the lack of significant differences in dry matter contents of the roots of different sizes (each group of 9 roots was subdivided into 3 large, medium and small roots, respectively).

A final analysis was undertaken to address the issue of sample size and the duration of drying at the three temperature regimes. The roots employed were a group sample and the moisture loss from initial amount (100%) to complete dryness (0%) was evaluated. This data is presented in Fig. 3. The drying trend for 55°C, although more rapid, is quite similar to that presented for actual commercial ginseng dryers (Bailey *et al.*, 1993; van Dalfsen *et al.*, 1992, 1995). It is also apparent that determination of 0% moisture at 48 hours may be problematic and that 72 hours would be most appropriate. It is interesting that the trends for both 70 and 105°C are, for all practical purposes, identical. Drying is rapid in the first 20 hour period. Although moisture could be assessed at 24 hours with confidence, delaying final weighing until 48 hours would ensure complete drying.

Research was conducted using temperatures of 55, 70 and 105°C. Temperatures above these(research conducted, but not reported herein) rapidly caused physical damage to the root samples. Temperatures below these behaved quite similar to actual dryer regimes and, hence, root drying was slow. The best drying regime for the objectives established is one that does not cause physical or chemical damage to the sample roots and has minimal time duration. Results indicate that there are differences among the three temperature regimes tested. Careful usage of the 70°C regime over a period of two days in a convection drying oven has merit.

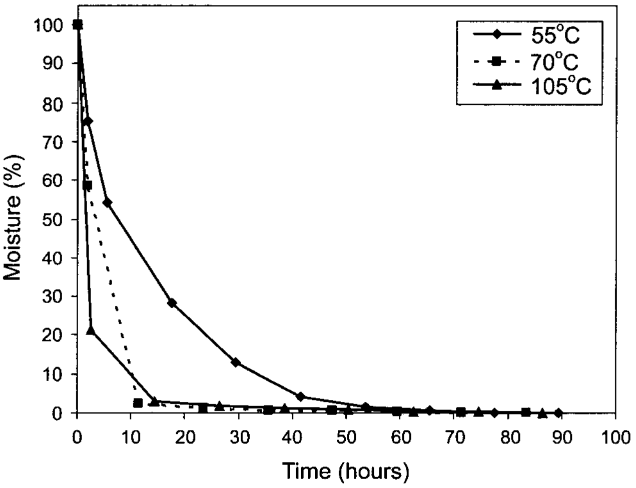

Fig. 3. Ginseng root moisture content (percentage of initial moisture) for drying at 55, 70 and 105°C.

CONCLUSIONS

This research examines the nature of high temperature drying of fresh North American ginseng roots. Its objective is to provide a method for rapidly drying roots for factual information to enhance dryer management decision making. Supplemental to this, the nature of ginseng root rehydration was also considered.

Research was conducted using drying temperatures of 55, 70 and 105°C. Temperatures above these rapidly cause substantive physical damage to the root samples and seriously compromise the dry root values determined. Temperatures below these behaved quite similar to actual dryer regimes(approximately 38°C). Hence, root drying was slow and did not provide sufficient lead time to allow optimum decision making of the drying regime. The best regime for rapid drying is one that does not cause physical or chemical damage to the sample roots and has minimal time requirements. Laboratory results indicate that there are differences between the three temperature regimes tested. Careful usage of the 70°C regime over a period of two to three days in a convection drying oven has distinct merit.

If roots are immersed in water for minimum amounts of time, there is little rehydration. However, if this period is lengthy, several hours for example, then substantive rehydration can occur. The amount of rehydration is not uniform and increases with smaller diameter roots. The reason for this relates to the larger ratio of surface area to volume(circumference to cross-sectional area) that is found with decreasing root diameters.

The aforementioned research provides a simple yet reliable methodology for gaining insight into root dry weights in a fashion that may be employed in the enhancement of dryer decision making. It is recognized that although this increases the knowledge base, the art of ginseng drying still remains and continues to provide substantive challenges for both the researcher and producer.

ACKNOWLEDGEMENTS

This research was funded principally by Technology B. C. Grants from the Science Council of British Columbia (held by W. G. Bailey). Additional support was provided by Simon Fraser University and The Associated Ginseng Growers of British Columbia. All of these funding sources are most gratefully acknowledged. The assistance and support of Mr. G. P. Smith of Askom Farm, Lillooet, British Columbia was essential to the success of the research and is gratefully appreciated and acknowledged.

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