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FACTSHEET

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# GINSENG DRYER OPERATION

The drying of ginseng roots is an important operation that can have a significant impact on the quality of the dried root. This factsheet provides some background information on drying in general and some specific information relating to drying ginseng roots.

## SAFE STORAGE PERIOD

Ginseng like other agricultural crops is dried to preserve it for long term storage. Safe storage of crops depends on three inter-related factors; product temperature, product moisture content, and time. Examples of safe storage periods are provided for shelled corn (Table 1) and wheat, oats and barley (Figure 1). This type of information has yet to be published for ginseng, however, observe that increases in product temperature and moisture content reduces the safe product storage time. In other words, ginseng growers have a limited amount of time to dry (reduce moisture content) that is a function of product temperature to prevent spoilage.

## FINAL STORAGE MOISTURE CONTENT

Li and Morey (1987) selected a optimum final moisture content for ginseng of 8 to 10 percent (wet basis). They report that this is in agreement with that adopted by ginseng growers. This moisture content should be considered safe for individual roots and not as the average of all roots in the dryer or in a ginseng drum. For example, if the actual moisture content ranges from 4 to 14%, then localized spoilage could occur in the high moisture area. Reynolds (1997) indicates that the correct moisture content as determined by the "snap" rating of dried ginseng may depend on root diameter.

**Table 1 Safe storage period for Corn**

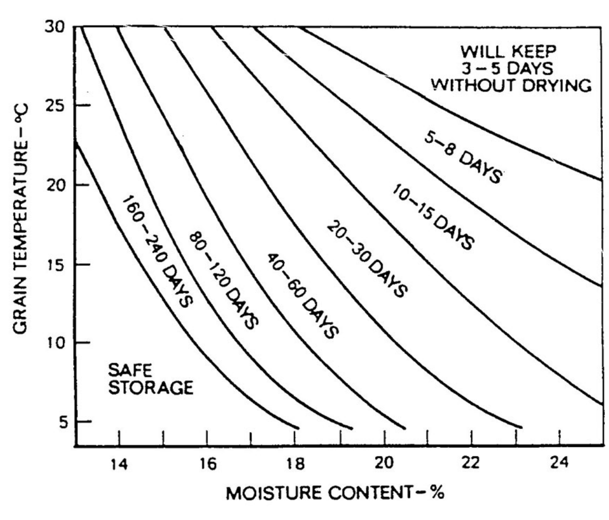
The safe storage period for corn[1] (in days) by storage temperature and moisture content [criterion: $CO_2$ development (dry matter loss<1.0%)]

| STORAGE AIR TEMPERATURE | | MOISTURE CONTENT (%,W.B.) | | | |
|---|---|---|---|---|---|
| (F) | (C) | 15 | 20 | 25 | 30 |
| 75 | 24 | 116 | 12 | 4 | 2 |
| 70 | 21 | 155 | 16 | 5 | 3 |
| 65 | 18 | 207 | 21 | 7 | 4 |
| 60 | 16 | 259 | 27 | 9 | 5 |
| 55 | 13 | 337 | 35 | 12 | 7 |
| 50 | 10 | 466 | 48 | 17 | 10 |
| 45 | 7 | 726 | 75 | 27 | 16 |
| 40 | 4 | 906 | 94 | 34 | 20 |
| 35 | 2 | 1,140 | 118 | 42 | 25 |

*Source: Brooker, Bakker-Arkema, & Hall (1974)*

[1]Storage times given are those beyond which loss in corn quality will bring about a lowering of grade. It should not be inferred that corn held within these limits will suffer no loss in quality.

**Figure 1. Effect of temperature and moisture content on allowable storage time of wheat, oats and barley**




*Source: Friesen & Huuminicki (1986)*

Table 2 shows the results of his study where he reconditioned (re-wetted) root and determined snap ratings for various root diameters and moisture contents

**Table 2. Effect of moisture content on the "Snap" rating of dried ginseng**

| | | Moisture Content (%) | | |
|---|---|---|---|---|
| | | Snap Rating | | |
| **Root Size** | **(dia)** | **Good** | **Poor** | **Unacceptable** |
| Fibers | (<7 mm) | <5.5 | 5.6-7.4 | >7.5 |
| Small | (7-12 mm) | <5.5 | 5.6-7.9 | >8.0 |
| Medium | (12-17 mm) | <7.0 | 7.1-8.9 | >9.0 |
| Large | (>17 mm) | <7.5 | 7.6-9.9 | >10.0 |

*Source: Reynolds (1997)*

## DRYING IMPACTS ON QUALITY

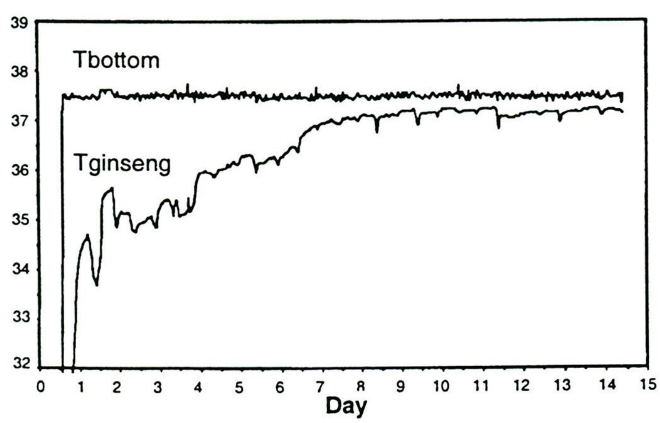
Drying air temperatures may have a significant effect on ginseng quality just as in other agricultural commodities. For example excessively high kernel temperatures in corn cause increased breakage, stress cracking and kernel discolouration and lead to a decrease in starch separation (millability), oil recovery, and protein quality. High kernel temperatures in wheat will damage its baking qualities. When considering what the safe air temperatures in a dryer are, note that the air temperature may be different from product temperatures, especially early in the drying process, and it is the actual product temperature that is critical. Figure 2 shows the internal temperature of a medium sized root in the middle of a research dryer compared to the air temperature at the bottom of the dryer at Simon Fraser University (Dryer C, Experiment 1991-I; Bailey, van Dalfsen & Guo, 1993). This dryer was loaded with 30 lbs of root per square foot of floor area and was operated to maintain an air temperature of 38 °C at the bottom of the dryer while the air was forced up through a column of 10 shallow trays of ginseng. The temperature of the ginseng will lag behind that of the air at the beginning of a batch dry and the temperature of the top roots will lag behind the bottom roots.

Several researchers have studied drying temperature and its impact on ginseng quality. Li and Morey (1987), Wilhelm (1990) and Van Hooren and Lester (1994) generally agree that low air temperatures ( less than 30 °C) result in an undesirable green internal colour. They also agree that high temperatures (greater than 40 °C) causes an undesirable brown internal colour. Van Hooren and Lester (1994) rated drying at 38 °C better than 35 or 40 °C.

## EQUILIBRIUM MOISTURE CONTENT

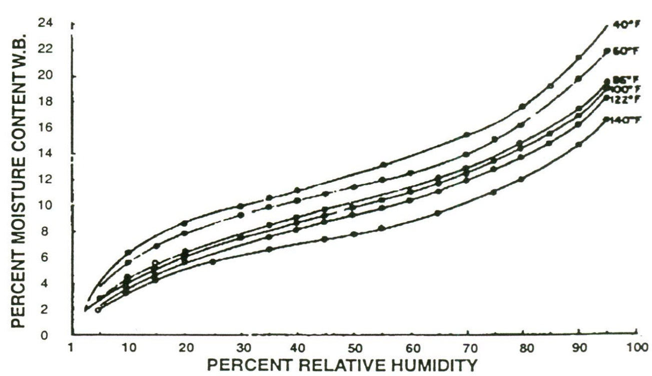
The concept of equilibrium moisture content (EMC) is very useful in discussing drying, because EMC determines the minimum moisture content to which a material can be dried with air of a specific quality (temperature and relative humidity). The EMC is defined as the moisture content of the material after it has been exposed to a particular environment for an infinitely long period of time. In other words, the material is in equilibrium when it loses as much water as it gains with no net change in moisture content. The EMC is dependent upon the humidity and temperature conditions of the environment as well as the material itself. The EMC reached when the material loses moisture (drying) is termed desorption EMC and those values may be different than the adsorption EMC reached when the material gains moisture (rewetting or conditioning). Figure 3 provides an example of how EMC's depend on temperature using shelled corn as an example. Table 3 provides an example of the difference between adsorption and desorption EMC's for the shelled corn at the same temperature. Notice that the difference in EMC's can be as much as 2% wb for corn.

**Figure 2. Dryer C temperatures**




*Source: Bailey, van Dalfsen & Guo (1993)*

**Figure 3. Equilibrium moisture content curves for shelled corn (desorption)**




*Source: Brooker, Bakker-Arkema, & Hall (1974)*

**Table 3. Desorption and adsorption moisture equilibrium contents (% WB) of shelled corn at 72°F**

| R.H. % | Desorption | Adsorption |
|---|---|---|
| 88.5 | 24.2 | 23.4 |
| 67.6 | 16.5 | 15.2 |
| 46.5 | 12.9 | 11.5 |
| 25.8 | 9.8 | 8.0 |
| 9.4 | 7.0 | 5.6 |

*Source: Chung and Pfost (1967)*

Reynolds (1997) has examined the EMC relationship by absorption for ginseng . Table 4 shows how the relationship between relative humidity (RH) and the mean equilibrium moisture content (EMC) of ginseng roots when they are conditioned or rewetted.. Note the large difference of moisture content with changing RH. The relationship between RH and EMC may also depend on the root's diameter. Similar data is required by drying ginseng root (desorption ) to show what happens in a commercial ginseng dryer.

**Table 4. Mean equilibrium moisture content of four size categories of ginseng roots when conditional at different relative humidities**

| RH (%) | Large (>17 mm)[2] | Medium (12-17 mm) | Small (7-12 mm) | Fibre (fibrous roots + <7 mm) |
|---|---|---|---|---|
| **40** | **5.3** | **5.2** | **4.8** | **5.3** |
| **45** | **5.9** | **5.4** | **5.4** | **6.2** |
| **50** | **6.2** | **5.7** | **5.7** | **6.4** |
| **55** | **7.0** | **6.9** | **7.4** | **7.6** |
| **60** | **8.9** | **9.2** | **9.4** | **8.4** |
| **65** | **9.2** | **8.9** | **9.6** | **9.0** |
| **70** | **9.6** | **9.7** | **10.0** | **11.1** |
| **75** | **10.3** | **11.0** | **11.9** | **12.4** |
| **LSD (0.05)** | **0.64** | **0.73** | **0.73** | **0.76** |

[2]Maximum root diameter in mm

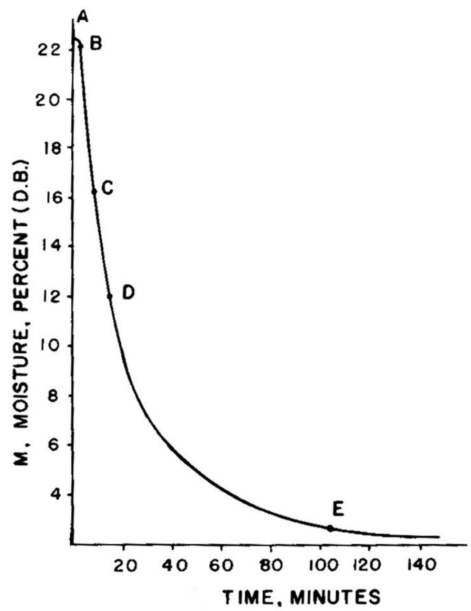
*Source: Reynolds (1997)*

# THEORY OF DRYING

Hall (1957) reports that farm crops differ from many other products which are dried, such as dust, paper, sand, stone, chemicals, etc. because of the organic content and presence of different plant components. The two major periods of drying are (1) the constant rate period and (2) the falling rate period. In the constant rate period drying takes place from the ginseng surface and is similar to evaporation of moisture from a free water surface. The rate at which moisture is evaporated is determined largely by the surroundings and is affected only a small amount by the ginseng itself. The point marking the end of the constant rate period occurs when the rate of moisture diffusion within the product decreases below that necessary to replenish the moisture at the surface. The magnitude of the rate of drying during this period is dependent upon: (1) area exposed, (2) difference in water vapour pressure (humidity) between the air stream and wet surface of the ginseng, (3) the coefficient of mass transfer, and (4) velocity of the drying air.

The falling rate period is entered after the constant rate period at the critical moisture content. The critical moisture content is the minimum moisture content of the ginseng that will sustain a rate of flow of free water to the surface of the ginseng equal to the maximum rate of removal of water vapour from the ginseng under the drying conditions. The falling rate period of drying is controlled largely by the ginseng and involves the (1) movement of moisture within the material to the surface by liquid diffusion, and (2) removal of moisture from the surface. The falling rate period of drying can be divided into two stages: (1) unsaturated surface drying and (2) drying where the rate of water diffusion within the product is slow and is the controlling factor. The surface is no longer a continuously wet surface but only partially wet, the rate of water movement being proportional to the fraction of the surface that is wet. Figure 4 shows a generic drying curve where:

**Figure 4. Drying curve**




*Source: Hall (1957)*

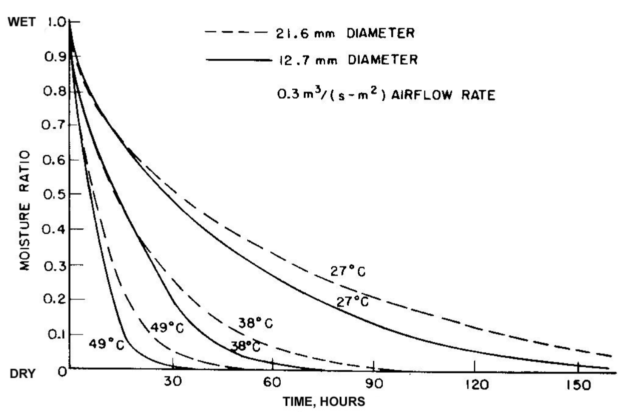
The drying rate of ginseng can be readily influenced by the operator only in the constant rate or early drying period. Using high temperatures at the end of the drying cycle may cause heat damage and will not increase the drying rate during the falling rate period.

# DRYER AIR TEMPERATURE

The published research shows that drying at 38°C from start to finish gives the best results from a root quality standpoint. Some growers believe that quality is improved by starting at lower temperatures and slowly building up to 38°C. Other growers believe that if you start at higher temperatures (above 38°C) the rate of drying will be quicker, then temperatures are lowered after the root has wilted (30% moisture content wb) to prevent darkening or carmelization of the root. Some growers recommend drying at 37°C or lower to reduce the risk of root damage.

Generally, begin drying with temperatures at least above 30°C and use temperatures below 38°C after root wilt. Using higher temperatures at the beginning of the cycle will reduce drying times as indicated by Figure 5. However, ensure that the root temperatures throughout the dryer are always within safe limits to prevent reduced ginseng quality. **The dryer's heater should be controlled by the temperature of the air just before it reaches the root. The heater will operate to maintain the temperature in the dryer.**

**Figure 5. Moisture ratio vs. elapsed time for samples harvested in July**




*Source: Li & Morey (1987)*

# AIR RELATIVE HUMIDITY

Air carries moisture (water vapor) with it. The amount of water vapor that air can carry is dependent on its temperature, the warmer the air the more moisture it can carry. Relative humidity is the ratio of the amount of water vapor actually present in the air to the greatest amount possible at that same temperature. When relative humidities are compared it should always be done at the same temperature, otherwise RH's do not directly reflect the amount of moisture in the air of different temperatures. It is the water vapour pressure that actually moves water from a high pressure to a lower pressure (hopefully from the root to the dryer air). If a constant 38°C dryer temperature is used then it is fairly safe to compare relative humidities recognizing that there is some temperature variation in the dryer. Pyschrometric charts are available to determine water vapour pressures based on temperature and relative humidity if RH's are compared at different temperatures.

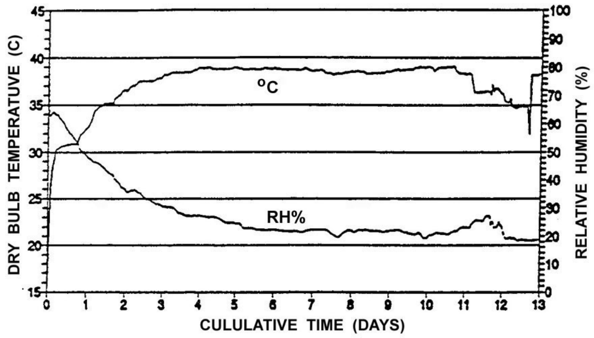
If the relative humidity of the air in the dryer is too high the ginseng root will no longer lose moisture even at high temperatures once the root reaches its equilibrium moisture content (EMC). If the relative humidity (RH) is too low the small roots in the dryer will become over dry before the large roots dry sufficiently to remove the batch of root from the dryer. Table 4 by Reynolds (1997) shows the EMC's for ginseng roots when they are rewetted or conditioned (absorption).

Similar data is required by desorption or by drying ginseng root to show what happens in a commercial ginseng dryer. However, the absorption data (Table 4) seems to suggest that a ginseng dryer will have to be operated at a low RH (45%) to ensure that small roots have a good snap rating (Table 2) compared to large roots. The RH for desorption would be expected to be even lower than that for adsorption (Table 3). Since large roots are the last to dry, perhaps the lower moisture content in smaller roots can be achieved by stopping the dryer when the larger roots have reached a moisture content that will provide a good snap rating but before they reach equilibrium with the low RH in the dryer. The smaller roots will have a lower moisture content as they dry more quickly and will likely reach their EMC.

Van Hooren and Lester (1990 and 1991) monitored commercial ginseng dryers including humidity and a typical temperature and humidity regime is shown in Figure 6. In a batch dryer the heater capacity and the amount of ginseng in the batch will determine the temperature and relative humidity in the dryer. At the start of the batch the heater will operate at maximum capacity until the desired temperature in the dryer is reached. **The RH in the dryer is lowered by opening the fresh air intake on the furnace, which in turn forces moist air out of the exhaust louvers located in the dryer. When the fresh air intake is opened more heat is required to warm the incoming outside air lowering the air temperature in the dryer.**

At the start of the batch dry it may not be possible to reach both the high temperature and low RH desired by the operator at the same time (Figure 6) depending on the heater's capacity and the amount of ginseng in the dryer. Higher RH's may have to be allowed to obtain the desired temperature. Conversely, at the end of the drying cycle, the heater operates very little. Air leakage in many commercial ginseng dryers is too great to maintain humidities above 30% RH (Figure 6). Air- tight construction, humidifiers or adding fresh root part way through the batch are all strategies that could be used to maintain higher RH's to prevent overdrying of the small root towards the end of the drying cycle.

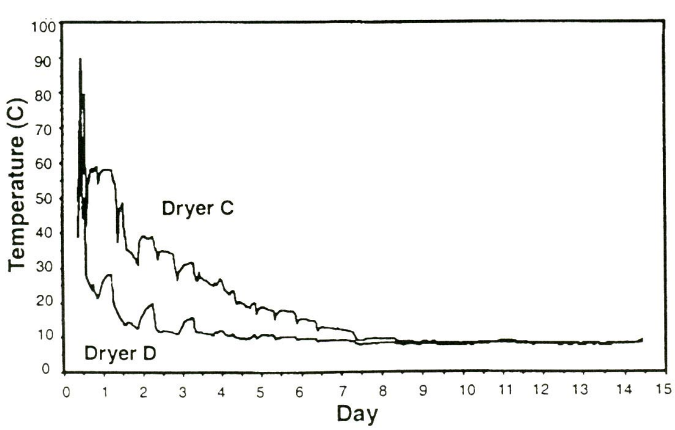
**Figure 6. Drying air history, 7 loads – site 2**




*Source: Van Hooren & Lester (1991)*

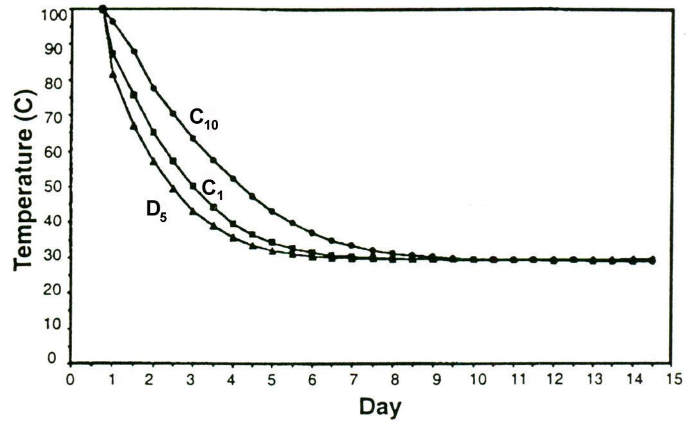
There has been some discussion in the ginseng industry that operating at too low an RH will cause overdrying of the surface of the root and slow the overall rate of ginseng drying. Figure 7 shows the RH measured in Dryers C and D from Experiment 1991-I described by van Dalfsen, Bailey & Guo (1992). Figure 8 shows the drying curve for the bottom and top tray (Trays 1 and 10 respectively) from Dryer C and Tray 5 from Dryer D. Dryer D could not be maintained at 30% RH because it was not air-tight enough when only loaded with one tray (Tray 5) at 3 lbs of root per sq. ft. of tray area. Dryer C maintained a higher RH because it was loaded with 10 trays all at 3 lb/sq.ft. Tray 10 of Dryer C would have been exposed to a higher RH than Tray 1 because the air was forced up from tray 1 to tray 10 rising in RH and being cooled at the same time. The trays in Dryer C were not rotated during the dry. Thus Tray 5 of Dryer D was exposed to the lowest RH and Trays 1 and 10 of Dryer C were exposed to progressively higher RH. The root exposed to the lowest RH (as low as 10%) dried the fastest. Drying at too low an RH **will** overdry the smallest roots.

**Figure 7. Dryer relative humidities**




*Source: van Dalfsen, Bailey & Guo (1995)*

**Figure 8. Effect of relative humidity on ginseng drying rates**




The furnace manufacturers sell relative humidity measuring equipment with their furnaces. Stand alone temperature/relative humidity chart recorders are available as well as electronic wet bulb and dry bulb temperature measuring systems. The electronic system is a little more convenient to use. These devices should both be manually checked for accuracy with a sling pyschrometer, which measures wet and dry bulb temperatures. A sling pychrometer costs about $70.00. Household humidity measuring equipment is not very accurate for a valuable crop such as ginseng.

## AIRFLOW RATE

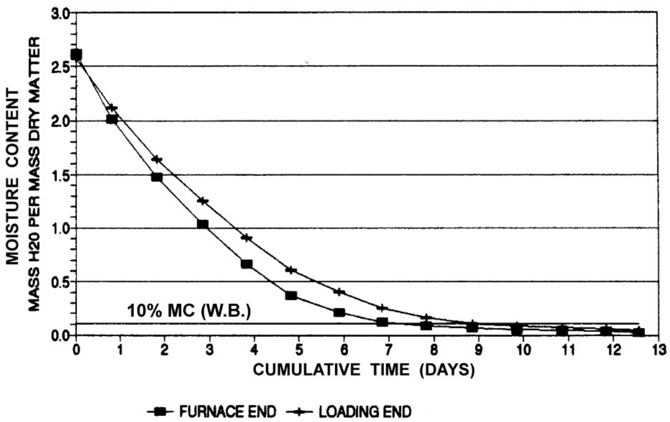
As ginseng loses moisture, the boundary layer of air surrounding it tends to be saturated with moisture due to the localized moisture buildup. Air movement dissipates this saturated air and replaces it with drier air, thereby tending to increase the rate of drying. The drying rate increases with air velocity until a point is reached where further increases in air velocity have little or no further effect on drying rates. When the loading rate of the dryer is high, increased airflow rates will also improve the drying rate. Commercial ginseng dryers have an airflow velocity of approximately 0.7 ft/s. In research ginseng dryers airflows of 0.7 ft/s have dried as quickly as airflows up to 1.8 ft/s when loaded at 30 lb/sq.ft. of dryer floor area (van Dalfsen, Bailey & Guo, 1992).

Some of the first tobacco kilns converted for ginseng drying did not force all the air through the column of ginseng. If drying air is allowed to bypass the ginseng, non-uniform drying is more prevalent and high loading rates should be avoided. Airflow should be uniform throughout the dryer to maximize the uniformity of the dry ginseng. In the modified tobacco kilns commonly used to dry ginseng a perforated floor is used to create uniform airflow through the dryer. Van Hooren and Lester (1991) reported that there was a difference in drying in one of the dryers they monitored from one end of the dryer to the other caused by non-uniform airflow (Figure

9). This non-uniformity could be corrected by changing the air duct layout, baffling the duct or enlarging the duct.

**The furnace's fan must operate continuously to circulate air in the dryer.** Higher airflow rates may speed drying during the first few days, particularly with high loading rates. Reducing airflow towards the end of the drying cycle may allow the operator to maintain higher RH's.

**Figure 9. Drying curves for 5 batches in a commercial dryer**




*Source: Van Hooren & Lester (1991)*

# LOADING RATE

Ginseng loading rates can vary significantly between dryers and operators as well. The dryers are operated in batch mode filled with fresh ginseng roots of mixed size that remain in the dryer until the largest roots in the batch are dry. Typically, batches take 8 to 14 days to dry depending on root diameter, loading rate and management of the dryer. In a heavily loaded dryer the heater will operate continuously at first when the roots are fresh and a lot of moisture is evaporated. Towards the end of the batch cycle the heater will operate sporadically as much less moisture is evaporated from the root as it becomes dryer. The heater's capacity is a critical factor in determining the dryer's maximum loading rate.

Roots that are exposed to the driest and warmest air (at the bottom of the dryer in most dryers) will dry more quickly than the root at the top of the dryer. The greater the volume of root in the vertical column, the slower the top roots will dry. If the top roots remain moist and warm too long before they are dried, they may spoil (Table 1) especially with high loading rates. Rotating trays from slow drying locations to fast drying locations and vice versa is one way to speed drying and also is a potential way to safely increase loading rates.
Van Hooren and Lester (1990, 1991) report many different loading rates for several commercial dryers on two farms and the information is summarized in Table 5.

**Table 5. Ginseng loading rates on two Ontario farms**

| | Year | (lb fresh/sq ft tray area | |
|---|---|---|---|
| Powell Kiln | 1988 | 28.3 | |
| | 1989 | 24.8 | |
| | 1990 | 30.6 | |
| | | Min Load | Max Load |
| DeCloet Kiln | 1988 | 30.7 | 38.4 |
| | 1989 | 25.6 | 26.6 |
| | 1990 | 34.8 | 45.1 |

Small lab dryers used to imitate commercial dryers (van Dalfsen, Bailey & Guo, 1995) showed that the drying rate of ginseng with loading rates of up to 75 lb/sq ft. is possible when the heaters had sufficient capacity to deal with the extra moisture load. The problem becomes how to load larger amounts of ginseng into a dryer without causing the shape of the ginseng to be affected by the weight of the ginseng pile during drying. Increasing the loading rate will directly reduce the cost of the dryer on a cost per pound dried basis even though drying times may be increased. Research suggests that drying a six inch deep layer of ginseng is possible without deformation of the root. Ten trays each with six inch layers of root is equivalent to a fresh loading rate of approximately 60 lb/sq.ft.

Be careful to match high loading rates with dryers having sufficient heater and fan capacities to maintain the desired temperature and humidity conditions throughout the dryer.

# TRAY MANAGEMENT

While loading more ginseng into a dryer is more cost effective it may increase the drying time of the top roots (slowest drying) in the dryer (van Dalfsen, Bailey & Guo, 1995). To improve the uniformity of the dry from the top of the dryer to the bottom and to reduce the time the batch of ginseng remains in the dryer, it is beneficial to rotate the trays from top to bottom. Also to reduce any non-uniformity due to position in the dryer (Figure 9), unload the dryer at the mid-point in the dry and reload the dryer by reversing (rotating) the trays. Place trays that were drying the slowest in a position where they will dry the quickest and vice versa. The rotation of trays once midway during the batch drying period will reduce the drying time by approximately one day (30 lb/sq ft, 38° C, .7ft/s).

Increased drying rates from rotating the trays from one end of the dryer to the other will depend on the non-uniformity of the airflow and temperature in the dryer. The practice of switching trays from one end to the other will tend to compensate for any non-uniformity that may be present. Note that rotating the trays will have more effect early in the dry (during the constant rate of drying period) and rotation near the end of the dry will not result in substantially quicker drying or greater uniformity.

## SIZE SORTING

Roots of different size will dry at different rates. To increase the uniformity of moisture content, roots may be size sorted by root diameter. Size sorted root can be dried in two ways. The large root can be placed in the bottom of the dryer and the small root in the top of the dryer. This tends to even out the rate of drying from the top to bottom compared to drying mixed root (van Dalfsen, Bailey & Guo, 1992). If trays are rotated part way through the batch dry, be sure to leave the large roots in the bottom (best drying) position. This technique will work even in bulk tobacco kilns where the ginseng is loaded from the end without convenient access to the trays for tray rotation or the removal of individual trays. The other way to use size sorted root is to load the same sized root in the same dryer. The uniformity of the final moisture content may be improved over drying mixed root. To provide even greater uniformity each tray should be removed from the dryer when it is dried. Convenient access to each tray during the batch cycle is required to make this technique practical. Some growers have removed the largest roots from the mix to be dried separately in an effort to reduce the drying time for the batch dryer and to increase the uniformity of the root's moisture content. It is then possible to pay closer attention to the large roots, which may have an especially high value and are more prone to spoilage or damage in the bulk dryer.

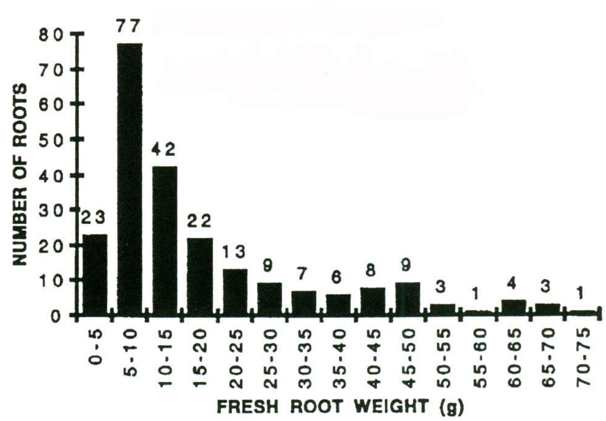
Figure 5 shows that the rate at which ginseng roots are dried is dependent on diameter (Li & Morey, 1987). Table 6 shows the moisture content (wb) of 70 roots after 8.5 days of drying in a food dehydrator. The table shows the average moisture content of 10 roots grouped first by diameter and then the same roots grouped by weight instead. Ginseng moisture content correlates better to root diameter.

**Table 6. Moisture content (M.C., %) of size sorted root dried for 10 days**

| GROUP DIA Mm | M.C. (%) | GROUP WT. Gm | M.C. (%) |
|---|---|---|---|
| 29.0-35.0 | 10.09 | 70+ | 9.23 |
| 26.0-29.0 | 8.69 | 50-70 | 9.66 |
| 23.0-26.0 | 7.41 | 37.5-50 | 7.15 |
| 17.7-23.0 | 5.43 | 25-37.5 | 5.43 |
| 16.4-17.7 | 5.13 | 15-25 | 5.59 |
| 13.5-16.4 | 4.62 | 10-15 | 4.11 |
| 11.5-13.5 | 4.27 | 10- | 4.49 |

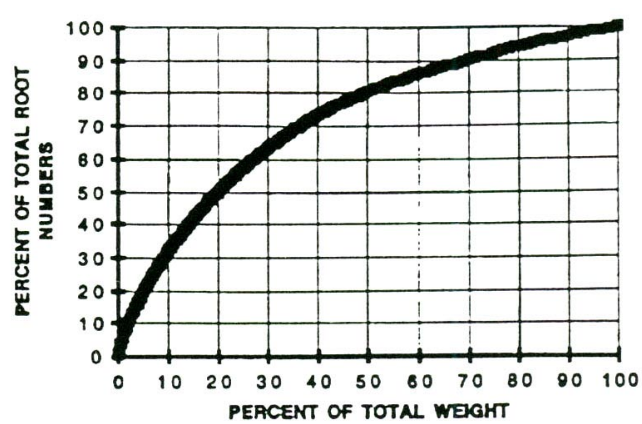
Ginseng roots have many laterals, prongs and hairs which make them very difficult to mechanically size sort. Removing only the largest roots by hand from an inspection conveyor will remove a significant portion of the overall weight. The distribution of root sizes from a British Columbia ginseng farm are shown in Figures 10 and 11. Figure 10 shows that there are typically many small roots but only a few large roots. However, Figure 11 shows that 10% of the roots (largest ones) represent 30 % of the total weight. A further trial demonstrated that 4 people could remove over 1000 lbs of the largest roots in one hour from a inspection conveyor. The team attempted to remove all the large diameter roots without worrying if some smaller roots entangled with the larger ones were taken as well. The 1000 lbs represented 25% by weight of the root placed on the conveyor. The labour cost ($10 per hour) for this size sorting is estimated to be less than 2 cents per dry pound of all the root passing over the inspection conveyor. It should be a simple matter to recover these costs by reduced drying times in the dryer and higher and more uniform moisture contents of the dried roots. The reduced drying times will also effectively reduce drying costs. The 2 cents per pound is less than 1% of the charge for custom drying.

**Figure 10. Distribution of root weight classes from a British Columbia North American ginseng garden in 1991**




*Source: van Dalfsen, Bailey & Guo (1995)*

**Figure 11. Distribution of root weight when roots are arranged in ascending weights from the garden sample as in figure 10**




*Source: van Dalfsen, Bailey & Guo (1995)*

## BATCH VERSUS CONTINUOUS DRYING

Drying ginseng in most commercial dryers is done on a batch basis where the all the ginseng of mixed root size is loaded into the dryer fresh and then removed when the largest root in the dryer is dry. This system usually requires concentrated efforts in digging, washing and loading the root in the dryer. If you are using one large dryer, this may not be an efficient use of labour. The dryer in the batch system must be capable of heating the entire batch of ginseng and heating large quantities of air to dehumidify the dryer as large amounts of moisture are given off initially. At the end of the dry very little heat is required. It may be possible to operate the dryer in a continuous mode where dried ginseng is removed from the bottom , all trays are lowered one level and fresh ginseng is loaded in the top of the dryer on a daily basis. This system allows the driest warmest air to be used to dry the driest root while still being very effective in drying the fresh ginseng as well. The heat requirement for the dryer will remain relatively constant and the heater could be approximately half the capacity of a batch dryer. Dryer efficiency may also be improved.

Continuous drying as described would be very labour intensive but would be well suited to woods grown ginseng operations where root is dug and washed daily. However, most commercial ginseng growers fill batch dryers every two weeks and rotate trays after about one week of drying. One way commercial growers could take advantage of some of the benefits of continuous drying would be to load the dryer half full at the start. After about one week (one half of the drying time), rotate the trays already in the dryer from top to bottom, then load the other half of the trays with fresh ginseng. The first roots would have lost more than 70 % of their moisture allowing the furnace to maintain the desired temperature and humidity at the bottom of the dryer even when the fresh ginseng is added. This technique would decrease the time required for the dryer to reach the temperature and relative humidity setpoints and increase the rate of drying at the beginning of the batch. With a fresh load of ginseng (moisture) after one week, even non-airtight dryers could be operated at higher relative humidities during the second week of the batch. The “half load” technique has the potential to increase loading rates, reduce drying time, halve the tray rotation requirements and minimize the overdrying of the smaller roots. An additional benefit is that the root washing operation is spread out over two wash periods providing more regular work for a potentially smaller work force.

## REFERENCES

Bailey, W.G., K.B. van Dalfsen and Y. Guo, 1993. ***The Role of Ginseng Drying in the Harvest and Post-Harvest Production System for American Ginseng.*** The 6th International Ginseng Symposium, Sept. 7 – 9, 1993. Seoul, Korea

Brooker, D.B., F.W. Bakker-Arkema and C.W. Hall. 1974. ***Drying Cereal Grains***. The AVI Publishing Company Inc., Westport, Connecticut, USA. 265p

Chung, D.S. and H.B. Pfost. 1967***. Adsorption and desorption of water vapour by cereal grains and their products.*** Trans. ASAE 10, 552 – 575.

Friesen, O.H. and D.N. Huminicki. 1986. ***Grain Aeration and Unheated Air Drying.*** Manitoba Agriculture, Winnipeg, Manitoba, Canada. 31p

Hall, C.W. 1957. ***Drying Farm Crops***. Agricultural Consulting Associates, Inc., Reynoldsburg, Ohio, USA. 336p

Li. Y. and Morey, R.V. 1987. ***Thin-layer drying rates and quality of cultivated American ginseng***. Transactions of ASAE, 30 (3) pp. 842 – 847.

Rafats, J. 1985. ***Quick bibliography series: Ginseng 1970 – 85.*** United States Department of Agriculture, National Agricultural Library, Beltsville, Maryland, 19 p.

Reynolds, L.B.1997. Personal communication.

van Dalfsen, K.B., W.G. Bailey and Y. Guo. 1992. ***Influence of Airflow, Loading Rates and Size Sorting on the Drying of American Ginseng***. Proceedings of the 8th International Drying Symposium (IDS'92) Montreal, Quebec, Canada, August 2 – 5, 1992. Drying '92, Part B pp 1370 – 1378. Elsevier Science Publishers B.V., The Netherlands.

van Dalfsen, K.B., W.G. Bailey and Y. Guo. 1995. ***Drying North American ginseng in British Columbia, Canada.*** Proceedings of the International Ginseng Conference (IGC'94) Vancouver, British Columbia, Canada, July 17 – 22, 1994. pp278 – 291. Simon Fraser University, Canada.

Van Hooren, D.L. and Lester, H.R. 1990. ***Methods to utilize tobacco kilns for curing (drying) and/or storage of alternate crops — interim report, 1989 year.*** Report No. 90 – 5103, Agricultural Energy Centre, Ontario Ministry of Agriculture and Food, Delhi, Ontario, 33p.

Van Hooren, D.L. and Lester. 1991. ***Methods to Utilize Tobacco Kilns for curing (Drying) and/or Storage of Alternate Crops — interim report, 1990 year.*** Horticultural Research Institute of Ontario, Delhi, Ontario, Canada. p84.

Van Hooren, D.L. and Lester, H.R. 1991a. ***Effects of conditioning and drying ginseng roots — interim report, 1990 year.*** Horticultural Research Institute of Ontario. Ontario Ministry of Agriculture and Food, Agriculture Canada Research Station, Delhi, Ontario, 13 p.

Van Hooren, D.L. and Lester, H.R. 1994. ***Effects of conditioning and drying ginseng roots — a 2 year study.*** Ontario Ministry of Agriculture and Food and Rural Affairs, Agriculture and Agri-Food, Canada Research Station, Delhi, Ontario, 22 p.

Wilhelm, L.R. 1990. ***Ginseng drying — the effect of drying air temperature and humidity upon quality.*** Transactions of ASAE, 6(5) pp. 635 – 639.

Williams, L. and Duke, J.A. 1978. ***Growing ginseng***. Farmers Bulletin Number 2201. United States Department of Agriculture, Washington, D.C., 8 p.

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