MATURE POTATOES PREFERRED FOR QUALITY PRODUCTS

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Tuber maturity at harvest is a key factor in producing high quality potato products. Generally, mature potatoes, whether they are used straight from the field or from storage, produce the best chips, crisps and dried potato products, as well as performing best out of storage for fresh use.

Processing companies want tubers with high dry matter (DM) and low reducing sugar levels. Such tubers give the best yield of chips from a given weight of raw potatoes. They fry faster, take up less oil and retain a light brown colour.

The stage of maturity at harvesting affects the DM, yield and sugar levels (sucrose, glucose and fructose) of potatoes destined for processing as well as the keeping quality and reconditioning potential of stored potatoes. High reducing sugar (glucose and fructose) levels are undesirable in process tubers because they lead to the formation of dark Maillard pigments during frying.

Immature tubers may process well immediately after harvest but they rapidly lose quality in storage. This is related to increases in glucose and fructose levels as well as shrivelling due to water loss and susceptibility to rots. For this reason, all potatoes, except those for immediate consumption, should be allowed to become fully mature before they are dug.

This article discusses how to determine when a crop has reached both physical and physiological maturity and factors affecting maturity.

WHAT IS MATURITY IN A POTATO CROP?

Processing maturity is often confused with physical maturation, where vine or tuber growth ceases. Many potatoes can complete physical growth without being mature for processing purposes. The major factor limiting the quality of potatoes for processing is their rate of production of reducing sugars in storage. The level and availability of sucrose at harvest is a critical factor determining the initial rate of reducing sugar formation in storage.

Most of us are familiar with immature or "new" potatoes. Tubers which are dug early have easily rubbed-off skins. They tend to be sweeter, and more moist and waxy, in contrast to more mealy, floury, and thicker-skinned mature tubers. Immature tubers are also more likely to have undesirably high levels of glycoalkaloids, especially after storage.

Physical measures such as vine appearance, yield, tuber size, skin set, DM and specific gravity have all been used to indicate tuber maturity. However, a more reliable way of determining tuber storage and processing quality is to use physical indicators along with chemical measures of, for example, glucose and fructose, sucrose, starch, free amino acids, and proteins (particularly enzymes). Processors prefer tubers with high starch and low levels of sucrose, fructose and glucose.

Dry matter (and specific gravity): DM is an important quality characteristic directly affecting the amount of product recovered during processing. A specific gravity between 1.08 to 1.10 or DM between 20 and 24% is preferred for potato crisps with slightly lower levels for french fries. High DM and specific gravity indicate high tuber starch content.

Generally, a seasonal increase in yield is matched by an increase in DM and specific gravity. However, near maturity there is often an increase in yield with a decrease in DM or vice versa, dependent on variety. Crop nutritional conditions and certain vine killing methods can also affect DM and specific gravity.

Vine maturity: As the crop reaches maturity the leaves and stems begin to lose their green colour, wither and die. Maturity is achieved with maximum DM content of tubers and loss of about 70% of foliage.

An abrupt break in growth caused, for example, by mechanical removal of foliage, will prevent further transfer of nutrients from tops to tubers. Consequently, tubers will have reduced DM and different chemical composition from those which mature normally.

In contrast, if tops are allowed to die down slowly then the plant will move sugars from the leaves and stems to tubers where they are turned into starch. Slow die down can be achieved naturally, or through appropriate use of slow-killing herbicides such as diquat (Reglone).

However, if tubers are harvested before this process is complete, high levels of sucrose in the tuber can be converted into undesirable glucose and fructose during storage. A glucose content of less than 0.1% on a fresh weight basis is required for crisp processing.

Skin set: The strength with which the skin is held on the tuber increases steadily over about 10 days (depending mainly on temperature and moisture) following vine destruction and is greater in mature crops. A thicker skin helps the tuber to withstand harvesting operations and reduces injury. Skin set is also used to indicate tuber maturity. If the skin rubs off easily (sometimes called the "thumb-test") the tuber is immature. Increasing difficulty in rubbing off the skin is experienced as it thickens. Several instruments have been developed to measure these forces and to provide a scientific and objective alternative to the "thumb test". A field or portable tester has also been developed. Skin strength values vary depending on where they are performed on the tuber. Accuracy of results is improved when tests are done on relatively large numbers of tubers.

Chemical maturity: As potato tubers increase in size and the crop matures, the amount of free sugars in the tuber decreases. When the sugars drop to a minimum level, the tubers are considered to be "chemically mature". This stage usually coincides with maximum DM accumulation and indicates that the crop is ready for harvest. Chemically immature potatoes contain high sucrose which breaks down to produce glucose and fructose after the tubers are harvested.

In many northern parts of the USA and Canada, chemical maturity monitoring (CMM), the analysis of sucrose and glucose contents in tubers, is used to determine both the chemical maturity of the crop and the effect of various management practices on crop quality. Sucrose content gives a good estimate of potential processing quality before harvest while glucose content

measured during storage gives the best estimate of immediate processing quality. To ensure processing quality direct from long term storage, a sucrose level at harvest of less than 2.8 mg/g tuber on a fresh weight basis is acceptable. Blood glucose monitors, the YSI biochemical analyser, and HPLC (high performance liquid chromatography) have all been used for these analyses with good agreement between methods.

However, sucrose levels vary between varieties and growing locations. The best levels are often reached long before acceptable tuber size so levels should be used in conjunction with optimum DM and yield to predict harvest ability. Further research is needed to determine the usefulness of sucrose measurements for New Zealand potato cultivars and conditions. Sucrose ratings also increase shortly after heavy rain because tuber growth recommences. They may be a useful guide to storage potential for crops experiencing heavy rain near maturity.

Pre-conditioning treatments (extended curing at 15-18°C) can be used for crops which are harvested before chemical maturity is reached. In a normal curing regime tubers are held at storage temperatures near 15°C with relative humidity near 95% for up to two weeks after harvest to promote suberisation and wound healing. If tubers are chemically immature at harvest extending the curing time will help prevent excessive glucose and fructose accumulation in storage. During curing, sugars are either used up in respiration or are converted into starch. Depending on the amount of sugars present at harvest, several weeks of pre-conditioning may be required before tubers are suitable for processing or long term storage.

FACTORS AFFECTING MATURITY

Variety

Varieties differ in the length of time taken to complete their growing cycle. Early maturing varieties include Jersey Benne, Rocket and Kennebec. Main crop varieties such as Fianna and Rua continue to grow for a much longer period, and varieties such as Ilam Hardy and Sebago are mid-season in their maturity. The length of time from emergence to maturity (or vine die down) will differ with site and season because it is temperature and day length dependent, but it will also vary depending on the availability of water and nutrients and the incidence of disease (especially late blight and early blight).

Environmental factors

Planting date: The longer the season the plants have for growth, generally the greater the yield potential and DM content of the tubers. If the crop has to be lifted before the tops die down because of the onset of cold soil temperatures, sugars could also be higher at harvest. A later planting date can mean that there will be fewer days from planting to maturity because of the day length effect. However, late planting usually leads to late maturity. Time from planting to emergence is a contributing factor to crop maturity and depends on the physiological maturity of the seed at planting.

Soil moisture: Soils with low moisture-holding capacity, such as sandy or light loamy soils, usually produce the highest DM in potatoes. Potatoes respond to ample soil moisture by an

increase in yield, but this will tend to lower their DM. However, in hot weather, which increases the respiration rate of the plant, water will lower soil temperature and less solids will be lost by respiration. So under hot conditions added water may increase DM. This means sandy soils have an advantage in wet seasons because they will produce tubers with increased DM compared to clay and peat soils, which will be wetter and colder. However, in a dry season, sandy soils will give lower yields of higher DM tubers unless irrigation is applied. In a hot season, clay soils retain the water better and stay cooler, so tubers with higher DM and less sugars are the result. There are, therefore, two opposing effects to consider:

- high soil moisture usually leads to lower DM and delayed maturity but,
- moisture lowers the soil temperature and respiration rates and minimises the loss of carbohydrate reserves resulting in increased DM and earlier maturity.

Seasons of heavy rainfall, especially if it falls late in the season, cause subsequent problems with stored potatoes used for processing. Late rain encourages vines to grow on, delaying senescence, and possibly preventing full maturation. Tubers often have high sucrose levels at harvest which can lead to unacceptably high glucose and fructose levels in the stored crop.

The ideal irrigation policy is to maintain uniform availability of water throughout the growing season with some drying off prior to full maturation. Varieties differ in their tolerance of water stress. Russet Burbank is a cultivar well known for its lack of tolerance to variations in water availability.

Temperature during the growing season: Temperature is one of the most important factors affecting the metabolic activities of the potato plant. It influences absorption of nutrients and their movement within the plant, rate of photosynthesis, respiration rate, and movement of organic solutes, length of growing season and therefore physiological maturity of tubers at harvest and their DM.

Tuber quality is best with warm day and cool night conditions. Higher day temperatures (even as high as 30°C) encourage high photosynthetic activity in the potato plant, provided water or other requirements are not limiting. Cool nights (10-15°C) provide good tuber quality because cooler temperatures lower respiration rates, allowing more of the accumulated sugars from the leaves to be stored as starch in the tubers. If the plants are under stress (e.g. due to high night temperatures, water stress, diseases) and respiration demand exceeds starch production from photosynthesis, this can lead to a nett loss of starch from the tuber. This situation can lead to sugar end browning in french fries.

Low soil temperatures (below 8-9°C) can cause the development of high levels of glucose and fructose as starch degrades, leading to undesirable, dark- coloured Maillard browning compounds in fried products. Some cultivars are more susceptible to this cool temperature sweetening than others. A trade off may need to be reached for process potatoes between allowing the crop to reach full maturity and digging earlier to prevent exposure to low temperatures. Temperatures below 10°C are also undesirable during harvest as tubers are more vulnerable to bruising at lower temperatures.

Nitrogen: Nitrogen (N) promotes vigorous and prolonged vine growth. Reasonable amounts (50-250 kgN/ha) of N and other fertilisers are required for maximum yields. Optimal amounts

depend on variety, soil fertility, location and length of growing season. Delayed maturity can occur if very high N fertiliser rates (greater than 300 kgN/ha) are applied, resulting in lowered DM, increased reducing sugars and poor chip colour after storage.

DM content tends to decrease as soil fertility increases. High DM levels are usually achieved in the absence of fertilisers, but this usually results in reduced yields.

The objective of a fertiliser programme is to control the N supply so that adequate N is available to produce moderate top growth prior to tuber formation. From then on N is required to maintain the vegetation in a healthy state and to meet the needs of the developing tubers. Excess N late in the season may delay tuber maturity in late season cultivars. The controlled supply of N can allow maturity time to be managed. In some areas nitrate N levels in petioles are measured routinely in the growing crop to monitor the need for applied N. In other places these measurements vary too much to be useful. An alternative approach is to assess total plant N uptake. Further research is required to determine an appropriate N fertiliser model for New Zealand cultivars and conditions.

Pests and diseases: Diseases and pests can cause early die-back of vines leading to a reduction in yield and DM. The physical and chemical maturity date of the crop will also be advanced.

In summary

Mature tubers produce better crisps and french fries, especially out of storage, because they are generally higher in DM and their chemical composition, particularly the level of sugars, is more suited to these purposes.

Mature tubers:

- have higher DM
- have lower levels of sucrose and reducing sugars
- are less likely to break down starch to produce high levels of reducing sugars in temperature controlled storage
- have thicker skins which are more resistant to damage during harvest and subsequent storage
- do not shrivel or lose water as much during storage
- are less susceptible to storage diseases.

Crops in which the tops are allowed to die down slowly will generally have higher DM and lower sugar levels than those harvested while the tops are still green. Skin set is important for minimising injury from harvest operations, and reducing respiration losses in the tuber.

Chemical maturity monitoring (CMM) is used to determine the changes in chemical status as a crop approaches maturity. This method has been used to test for harvest readiness and storage potential of tubers, particularly for Russet Burbank. Its value under New Zealand conditions may be worth investigating.

Many environmental factors influence the number of days taken for a crop to reach maturity. A balance between healthy tops and bulking of tubers is reached by managing the availability of water and N at the various stages of growth. This is difficult in New Zealand because of erratic

rainfall but is easier on irrigated lighter soils.

In New Zealand, the incidence of potato crops not reaching full maturity before cold soil temperatures make harvesting a necessity is not as critical as in some areas of the USA and Canada. In most North Island locations vine die-down occurs naturally or from only light frosts, ensuring optimum DM levels in crops. If there is any risk of cold conditions setting in before natural die-down (such as in some South Island sites), crops should be managed (e.g. fertiliser and water) so that vines are encouraged to die-down in time, although this must be balanced against gaining maximum growing period, yield and DM.

If maturity is not properly achieved before harvest, tubers should not be stored but processed as soon as possible. If this is not possible because of the quantities involved, pre-conditioning treatments (15-18°C for three weeks or longer) could be used with tests for sucrose, fructose and glucose to monitor effectiveness.

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Bibliography

A wide range of scientific journals were searched to find information for this article. These included: *Potato Research, American Potato Journal, Canadian Journal of Plant Science, J Sci Food Agric, Potato Chipper, Chipper/Snacker, J Plant Physiology, Hortscience, Postharvest Biology and Technology*, and MAF, DSIR and C&F publications. Useful books were: "Potato Processing", Talburt and Smith, 1975. AVI Publishing Company and "Potato Science and Technology", Lisinska and Leszczynski, 1989. Elsevier Applied Science. The internet was also searched for information from web sites. Particularly useful sites were: www.spud.co.uk; and www.gov.mb.ca/agriculture/potato.

The following text is to be boxed in the journal article and placed somewhere near the relevant paragraph in the text.

Dry matter (DM) content of tubers is traditionally measured by drying minced samples at 80°C until a constant weight is reached. This is time consuming so the specific gravity of tubers (determined by weighing the tubers in air (Wa) and in water (Ww) and calculating specific gravity (SG) by the equation SG = Wa / (Wa-Ww)), is used to predict the DM.