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Passam H.C.

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THE CURING OF YAM (*Dioscorea spp.*) TUBERS FOR IMPROVED STORAGE

H. C. Passam
Agricultural University of Athens,
Laboratory of Vegetable Production,
Greece,

Abstract

Tropical root crops such as sweet potato and Colocasia are also cultivated in the Mediterranean region. In addition, yams (Dioscorea spp), which are an important root crop especially in West Africa, have been grown in Greece on an experimental scale. Yam production is seasonal and storage under tropical ambient conditions often leads to considerable wastage. Curing of tubers at 35° C and 85+5% rh provides an excellent means of reducing storage losses due to the infection of wounds incurred during harvest and handling. The present paper describes some of the physiological processes that occur during curing and presents evidence that the prevention of decay by Penicillium (a common wound pathogen of yam) depends not only on the induction of suberin and the formation of periderm but also on the integrity and moisture content of the starch layer which forms at the wound surface. It is proposed that the cultivation of tropical and subtropical crops in the Mediterranean region provides an opportunity for extending research and collaboration in the field of tropical and subtropical agriculture.

Keywords

YAMS, DIOSCOREA, WOUNDING, STORAGE, CURING

1. INTRODUCTION

The tropical root crops are a group of plants which includes cassava (*Manihot esculenta* Crantz.), sweet potato (*Ipomoea batatas* (L.) Lam.), yams (*Dioscorea* spp) and the edible aroids (*Colocasia esculenta* (L.) Schott. and *Xanthosoma* spp. (L.) Schott.) and which provides the stable carbohydrate source for an estimated population of over 500 million people (Coursey, 1983; O'Hair, 1990).

Beyond their importance to the tropical and subtropical world, a number of these crops are becoming increasingly well-known in Europe. For example, sweet potato and Colocasia are cultivated in the Mediterranean, the former with an annual production of about 86,000 t being grown principally in Spain and Portugal and the latter on a small scale in Cyprus (3-4,000 t). Yams, which have been imported for some time to Britain from tropical regions, have recently been cultivated experimentally in Greece.

Yams are grown primarily in West Africa (90% of world production coming from Nigeria, Ivory Coast, Ghana, Dahomey and Togo) and are normally propagated vegetatively by the use of whole tubers or tuber parts. The vegetative period is relatively long (7-9 months) and after die-back of the vines the tubers may be left in the ground for upto 3-4 months or harvested and stored for the duration of the dormant period.

Losses during storage are known to be high and, depending on the species and the storage environment, may be of the order of 30-60% during the course of 3-6 months (Proctor et al., 1981). The principal causes of loss include:

1. Weight loss due to desiccation
2. Loss of carbohydrate and water due to respiration
3. Sprouting on breakage of dormancy
4. Microbial decay, particularly as a result of the infection of wounds
5. Losses due to rodents and insects.

Unlike potatoes and other temperate root crops, yams are highly susceptible to chilling injury and cannot be stored at temperatures below about 15°C. At subsistence-farming level, mature yam tubers may be left in the ground until required. Alternatively, they may be harvested and stored under cover or in a sheltered place so as to protect them from exposure to the sun and provide ventilation and security.

Certain post-harvest treatments can also be employed which contribute to an improvement of storage life and quality. For example, treatment of tubers after harvest with fungicide has been shown to reduce wastage (Thompson et al., 1977) whereas curing (ie. exposure of tubers to high temperature and humidity for a few days prior to storage) reduces both subsequent water loss and the incidence of decay by wound pathogens (Rivera *et al.*, 1974; Passam *et al.*, 1976 a,b; Been *et al.*, 1977).

Curing is a simple technique that has been applied to other root crops as well, eg. sweet potato. It is a particularly effective, low-cost treatment for yams because it does not demand elaborate facilities and does away with the need for expensive fungicides or other chemicals. Yams (*Dioscorea rotundata* Poir.) that have been grown locally in Greece are cured routinely at about 35°C and 85-90% rh and storage life is 5-6 months (Passam, unpublished).

The present paper describes some of the physiological factors that are involved in the curing process.

2. MATERIALS AND METHODS

Tubers of *D. rotundata* Poir., were grown locally or purchased, the country of origin being Jamaica. Tubers were bisected under non-sterile conditions and stored at 85+5% rh and either 17+1°C, 25+1°C or 35+1°C. Microscopic observations were carried out on appropriately-stained hand-cut sections. Respiration measurements were carried out as described by Passam *et al.* (1978).

3. RESULTS AND DISCUSSION

Yams are predominantly annual plants and the tubers therefore serve as organs of both propagation and perennation. Passam *et al* (1978) have shown that at harvest, the rate of respiration is high (15 and 29ml CO_2 kg fresh weight-1 h-1 at 25 and 35°C respectively), but that as the tubers enter dormancy this rate declines to a low level (3 and 8 ml CO_2 kg fresh weight-1 h-1 at 25 and 35°C respectively), increasing again at breakage of dormancy (over 20 ml CO_2 kg fresh weight-1 h-1). This pattern of respiration is simliar to that of other yam species and also potatoes (Burton, 1966). However, as yams are normally stored at tropical ambient temperatures there may be a considerable loss of carbohydrate and water due to respiration even during the dormant phase (Passam *et al.*, 1978).

Whereas in temperate root crops, such as potato, dormancy enables the plant to survive a period of low temperature, in yams dormancy provides a means of survival during drought or dry periods. The dormant period varies between species and may be related to the particular habitat within which the species has evolved. For example, *D. cayenensis* (which is essentially a species of the West African forest zone where the dry season is very short) shows virtually continuous growth, a new vine arising almost as soon as an old one has died down. As shown in Table 1, the tubers of *D. cayenensis* thus exhibit a correspondingly short dormant period and do not store well even under optimum conditions. In contrast, D elephantipes, which is indigenous to the rocky, semi-desert areas of South Africa, spends the greater part of the year in a dormant state, the vine appearing for only a brief period during the short rainy season. Other species, such as *D. rotundata* and *D. alata*, which are adapted to a climate with a longer dry season than that of *D. cayenensis*, exhibit a duration of dormancy intermediate between these extremes.

Although dormancy ultimately controls the length of storage life (yams cannot be stored satisfactorily for human consumption once sprouting has occurred), mechanical damage incurred during harvest and handling, in conjunction with microbial infection of wounds, may cause considerable decay and wastage. If exposed wounds are not satisfactorily healed, rots appear within a few days and, under tropical ambient conditions, rapidly spread even to neighbouring healthy tubers.

When yam tubers are bisected or cut deeply they respond by an almost immediate increase in metabolic activity (Passam et al., 1976b). In particular, the respiration rate rises rapidly (Fig. 1) and there is an induction or increase in activity of certain enzymes, notably-amylase and acid invertase (Fig. 2). Invertase activity is highest in the layers of cells adjacent to the wound, but also develops in the region where periderm forms. Concomitantly, there is a mobilization of food reserves resulting in an increase in reducing and non-reducing sugars in the wound tissue (Passam et al., 1976b).

Histologically, three stages of wound repair may be observed, consisting of:

1. First, within 5-10 h of injury, the formation of adense starch layer at the cut surface
2. Secondly, the laying down of suberin in the inner layers of the starch-containing cells
3. Subsequent development of cork (periderm) beneath the suberized tissue.

Thus, on completion of the repair process, the tissues at the wound surface show a characteristic pattern of development, as indicated in Fig. 3. It has been established that both invertase and respiratory activity increase sequentially within the starch/suberin and periderm tissues as they form. Thus, maximum activity in the starch/suberin layer occurs when suberin is being deposited and maximum activity in the periderm corresponds to the period of cell division and periderm formation (Passam *et al.*, 1977).

Both the metabolic activity and the rate of wound repair are critically dependent on the temperature at which the tubers are held. As shown in Table 2, at 35°C suberization occurs within two days of bisection and periderm formation within four days. At 25°C, suberization and periderm formation occur within 3 and 5 days repectively, but at 17°C, although suberization occurs by the fourth day after injury, periderm is not observed until after ten days. By this time, unless the tubers have been treated with fungicide, the cut surfaces are normally severely infected with fungal growth.

As shown in Table 3, the wound respiration rate and the thickness of the suberized and periderm layers are all significantly affected by temperature. Visible infection by pathogens, such as Penicillium (Table 2), occurs within 3-4 days when tubers are stored at 17 or 25°C. The entire cut surface becomes colonized by the sixth day after injury and decay normally spreads beneath the wound so as to progressively affect the whole organ. In contrast, at 35°C, infection by Penicillium, which is a major wound pathogen of yam (Noon, 1978), is not, or seldom, observed.

In this experiment, yams were stored at high R.H. (85+5%). Although lower R.H. (50% or less) will suppress mould growth at all temperatures, it is also known in potato and sweet potato to reduce the rate of wound repair (Artschwager, 1927; Artschwager and Starrett, 1931). Moreover, in yams low rh provokes rapid drying and cracking of the starch layer. In consequence, tubers frequently become infected via these cracks so that even at 35°C considerable loss may occur.

From Table 2, it may also be discerned that at 17 or 25°C the first colonies of Penicillium appear on the starch layer at the cut surface before a complete layer of suberin has formed and 90% or more of the cut surface may be colonized by the time periderm is initiated. In this case, suberization and the formation of periderm do not prevent the invasion of the inner healthy tissues by the wound pathogen. By contrast, at 35°C colonies of Penicillium are seldom observed even though suberization and periderm formation do not occur until two and four days repectively after injury. From these data, therefore, it is evident that although suberin and periderm may play an important role in the prevention of the spread of infections, as originally shown by Weimer and Harter (1921), other factors must also be involved at 35°C, which is the temperature at which yams may be satisfactorily cured.

One factor that is particularly important in controlling the incidence of wound infection is the rate of growth of the pathogen. When Penicillium is inoculated onto boiled discs of yam the rate of fungal growth is maximal at 25-28°C. At 35°C, the rate of growth is less than half the maximum rate.

A second factor that is considered to be important is the moisture content of the starch layer at the cut surface. In yams, the surface starch layer is often very thick (sometimes as much as 1.5 mm). As shown in Table 4, if the cut tubers are kept at saturating humidity, so that the starch layer contains a higher percentage of moisture, the degree of infection increases and colonies develop even at 35°C. In contrast, if the surface starch layer is dried by passing a current of warm air across it for 15 min after cutting, the incidence of infection after seven days storage at 17 or 25°C is markedly reduced. The dry matter content of the surface starch layer in this case varies between 55 and 75% compared with approximately 30% in freshly-cut storage tissue.

In conclusion, it is affirmed that curing of yam tubers at 35°C provides a simple, but effective means of reducing losses due to microbial infection of wounds. The success of curing, however, does not rely solely on the formation of suberin and periderm, but relates to the integrity and moisture content of the surface starch layer. Finally, it is suggested that the further introduction of tropical and subtropical crops (such as yam in the present instance) to the Mediterranean region offers new opportunities for the extension of research and collaboration in the field of tropical and subtropical agriculture.

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Table 1. The dormancy of yam tubers in relation to habitat

Species	Vegetative cycle (months)	Habitat	Dormant period (months)
D. *cayenensis*	7 - 10	Wet forest	1 - 2
D. *alata*	8 - 10	Humid tropics	3 - 5
D. *rotundata*	6 - 7	humid tropics	4 - 5
D. *elephantipes*	*	Semi-desert	6+

* Life of vines dependent on incidence of rain

Table 2. Infection of the cut surface of *D. rotundata* by *Penicillium* in relation to the rate of wound repairs

Observation	Storage temperature		
	17° C	25° C	35° C
Days to suberization	4 - 5	3 - 4	2
Days to periderm formation	> 10	5	4
Days to first appearance of *Penicillium*	4	3	-
Days to 90% infection of cut surface by *Penicillium*	6	5	-

Table 3. Effect of temperature on the rates of wound respiration and wound repair of *D. Rotundata*

Observation	Storage temperature		
	17° C	25° C	35° C
Thickness of starch layer at wound after 7 days (mm)	06.-0.8	0.6	0.8-1.2
Thickness of suberized layer after 7 days (mm)	0.2-0.4	0.2-0.4	0.5 -0.7
Thickness of periderm after 7 days (mm)	absent	0.1-0.15	0.15-0.2
Rate of respiration before cutting (ml kg-1 h-1)	1.9	5.7	6.5
Peak of wound respiration (ml kg-1 h-1)	5.4	18.5	24.5
Rate of respiration 7 days after cutting (ml kg-1 h-1)	2.5	14.5	7.6

Table 4. Effects of temperature and humidity on Penicillium infection of bisected *D. rotundata* tubers

Treatment	% of total area of cut surface infected after 7 days at		
	17° C	25° C	35° C
Control (85 + 5% rh)	62.5	64	0
100% rh	67.5	84	4
Cut ends dried with air	10	24	0