Journal of Multidisciplinary Engineering Science and Technology (JMEST)
ISSN: 3159-0040
Vol. 2 Issue 6, June - 2015

Effect of Post-Harvest Water Washing, Chlorination and Curing on Respiration and/or Ethylene Production of Sound or Injured Cocoyam (Xanthosoma Sagittifolium L.) Corms in Storage.

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Abstract*—A combined pre-storage treatment involving water washing in association with chlorination (1% NaOCl) and curing (at 30 °C, 95 % RH, for 7 days) was tested on respiration activity of stored cocoyam (Xanthosoma sagittifolium L.) corms, in a factorial experiment with 3 replications. In a similar arrangement context, another investigation was conducted to determine the impact of damage infliction combined with curing, on the respiration and ethylene production of corms in storage. The respiration rates recorded after 2 weeks of shelflife, including the 7 days of curing, were significantly (P<0,05) different in intensity, and declined over time on cured and uncured corms. From a high average level of 19,5 ml CO_2/kg/hr reached after a few hours after harvest, the respiration rates were reduced during storage and stabilized nearing the average low level of 4 ml CO_2/kg/hr. This minimum intensity was reached faster (after 10 days) when chlorination and curing were applied versus the 15 days of time period this took for control corms. Respiration activity and ethylene production were significantly (P<0,05) affected by curing on injury inflicted corms. Damaging of corms shortly after harvest with no curing to follow, induced a noticeable increase to the highest level recorded of 39,9 ml CO_2/kg/hr in respiration and to a sharper rise (0,6 µl C_2H_4/kg/hr) in ethylene production. Injury infliction on cured corms instead brought a significantly (P<0,05) reduced rates in respiration (16,6 ml CO_2/kg/hr) and in ethylene production (0,2 µl C_2H_4/kg/hr) . Corms damaged 7 days after harvest but not submitted to curing had a comparable rate in respiration (17,9 ml CO_2/kg/hr) and instead a high level in ethylene release (0,6 µl C_2H_4/kg/hr), comparable to that obtained damaging of corms occurred without delay after harvest. In absence of initial curing , injury infliction favored decay infection, which contributed to a remarkable increase in both respiration and ethylene production.

Keywords*—Xanthosoma, chlorination, curing, respiration, ethylene production

1. INTRODUCTION

Xanthosoma is a dietary staple in regions of Asia, Africa, and the Americas. Both the leaves and rhizome-like side shoots (corms) are consumed (Quaye et al.,2010; Bikomo, 2013; 3). The harvested corms are often laid in the sun to dry adhering soil and then either piled in the shade, covered with straw or plantain leaver (cooke et al.,1988), or stored in underground pit (Obetta et al.,2007; Onweme, 1978).

Dry, well ventilated surrounding is usually considered best for ambient storage due to the severe danger of losses from attacks by microorganisms (Praquin and Miché, 1972; Obetta et al., 2007; Addisu et al., 2014). However, losses of 50 and 95% were recorded after 2 and 5 months storage, respectively, under ambient conditions of Dschang, in Cameroon (Praquin and Miché, 1972; Passam, 1982; Bikomo, 2013; Addisu et al., 2014). The postharvest pathogens *of Xanthosoma* are generally soil-borne organisms and thus may be well established in the corms at the time of harvest (Booth, 1978; Cooke et al;, 1988; Ugwuoke et al., 2008; Olayemi et al., 2012; Eze and Amadi, 2013).

Even in absence of decay, weight loss can be severe under ambient storage conditions due to water loss and respiration (Passam, 1982; Addisu et al., 2014). Respiration rate of root crops is known to decline after harvest, unlike that of climacteric products (Ryall and Lipton, 1979; Burton, 1982). The respiration rates of healthy stored cocoyam and taro corms were recorded under tropical ambient conditions, and averaged 8.3 ml CO_2/kg/hr and 4.6 ml CO_2/kg/hr respectively (Agbor-Egbe and Rickard, 1990). Increased temperature enhanced respiratory

activities in potato tubers, with about 10,5mg CO_2/kg/hr released at 25°C (Burton, 1982). Increased respiration is known to precipitate losses in stored crops by exhaustion of carbohydrates reserves (Onweme, 1978; Passam, 1982; Cooke et al., 1988). A respiration rise may result from exposure to high temperatures, anaerobic conditions or from pressure of wounds on crops (Burton, 1982). High temperature combined with high relative humidity during curing enhances the wound healing process in root crops (Bikomo, 1988). Reduced respiratory activity is therefore expected in cured corms. But harvest wounds and handling damages can induce increased respiration in commodity tissue and increased ethylene production in material such as root crops which do not normally produce ethylene (Ryall and Lipton, 1979; Burton, 1982; Eze et al., 2013; Paull and Ching, 2015). An increased production of ethylene was recorded at levels 4 folds higher in deteriorated cassava roots than in non-deteriorated products (Paull and Ching, 2015). However, it was observed that the corms of taro could produce a very low level of ethylene when stored in ambient conditions (Salcedo and Siritunga, 2011). Increased respiration and effectiveness and relatively increased production of ethylene may be helpful in detection of less apparent mechanical damages on stored root and tuber crops.

The objective of this study was to evaluate the impact of chlorination and curing on respiration of cocoyam corms and to determine the incidence of bruising on respiration and ethylene activity in cured and uncured corms.

2. MATHERIALS AND METHODS.

Corms of a local variety of cocoyam (*Xanthosoma sagittifolium* L.) were obtained from the experimental farm plot of the University of Dschang, in west Cameroon. The unwashed corms were sorted to remove product with injuries or decay, and randomly grouped into lots of 10 corms each.

Chlorination and curing effect on respiration of corms, and bruising impact on respiration and ethylene production of cured and uncured were tested in a factorial, completely randomized experiment. For chlorination, the corms were dipped for 2 mm in water containing 1% NaOCl from commercial bleach (5% NaOCl), in groups of 10 corms placed in nylon mesh (onion) bags. After dipping, the corms were placed on trays and air dried. Concentration of chlorine was monitored with a chlorine test Kit (Taylor Chemicals Inc., Spark, M.D, USA) using orthodolidine indicator. The corms were cured for 7 days at 30°C and 95% RH in growth chamber, or placed directly into a storage room at 25 ±1°c and 75 ± 5% RH for uncured products. After 7 days all the corms were placed in the 25°C storage room and held for an additional 3 weeks to approximate conditions which might be encountered in ambient storage.

Washing consisted of dipping corms in a 10 liter tap water containing bucket, to remove soil and dirt. For impact bruising, each corm was impacted once on opposite sides from a standard 1m height with a 150g steel ball dropped through a vertical column. The respiration rates of Xanthosoma corms was measured on previously water washed samples of 10 products, which were weighed and placed in 1,75 liter glass jars. Each treatment consisted of 3 jars arranged in the 30°C room with 95% RH (curing room) and 3 others in the 25°c and 75% RH ambient conditions room. After holding overnight, jars were sealed for 1 hour for measurement of CO_2 production. Syringes were used to take 0,5ml gas samples through rubber septa inserted in the jar lids. Samples were injected into a gas chromatograph (GC) for determination of CO_2 concentration. Daily measurements were made throughout the curing period (7days) and continued 10 days after the samples were transferred to ambient conditions.

Percent of CO_2 was converted to total milliliters of CO2 evolved per kilogram of corm tissue per hour using the following equation:

$$\frac{\%\ CO_2(\text{form GC}) * \text{ml (void space)}}{100 * Z * T}$$

Where:

Z = average total weight of corm/jar in kg

T= time (hours elapsed between jar sealing and gas sampling.

The void volume was obtained by measuring the volume of water remaining after complete immersion of corms in a jar previously filled with water.

To measure the effect of damage on respiration and ethylene production of cured and uncured corms, the products for that purpose were sized and selected for uniformity and freedom from injuries. Three 9,5 liter glass jars containing 10 individual corms each and fitted with inlet and outlet tubes were placed at 25°C and 75% RH. In these tests, air was passed through each jar at a flow rate of 100 milliliters per minute. Readings from the GC (in percent of CO_2) were converted to total milliliters of carbon dioxide evolved per kilogram of corm tissue per hour using the equation below:

$$\frac{\%\ CO_2 * \text{flow rate (ml/hr)}}{100 * \text{sample weight (kg)}}$$

Measurements were taken daily for two weeks.

Ethylene concentrations (ppm) read daily from the GC were corrected to total microliters of ethylene produced per kg of corm tissue per hour, according to the following transformation:

$$\frac{\text{ppm } C_2H_4 \text{ x flow rate (ml/hr)}}{1000 * \text{sample weight(hg)}}$$

Data analysis was processed using SAS analysis of variance method (SAS, 1982) with significant differences between treatment means determined using Duncan's multiply range test. Angular transformations were performed on data expressed as

percentages. All of the experiments were completely randomized design. There were three replicates of each treatment, consisting of 10 corms per replicate.

3. RESULTS

Results from the test of chlorination and curing on respiration showed that respiratory activity was significantly (P < 0,05) higher in freshly harvested and untreated corms (Table 1). They were respiring at rate averaging 19,5 mlCO_2/kg/hr after one day of storage, and exhibited declining respiration rates over time (Fig.1).

Table 1 Effects of pre-storage combination of washing, chlorination and curing on respiration of cocoyam corms after curing (7 days) and after storage (2 weeks).

Treatment	Respiration rates after curing (ml CO_2 kg^{-1} hr^{-1})	Respiration rates after storage (ml $CO_2kg^{-1}hr^{-1}$)
Initial curing		
No washing	09,8 a[y]	03,4 a
Chlorinated water washing	09,3 a[z]	02,3 a
Washing	08,4 a	02,9 a
No curing		
No washing	14,8 c	05,1 c
Chlorinated water	07,3 b	03,6 a
Washing	10,2 a	04,2 b

y Data are means of 3 observations

z Means within treatment not followed by the some letters are significantly different at 5% level by Duncan's multiple range test.

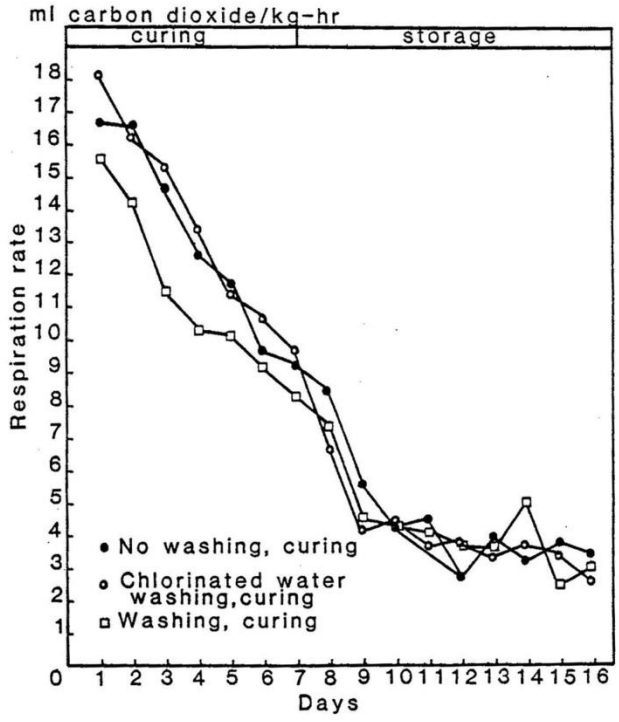

Figure 1 Respiration rates of chlorinated or non-chlorinated water washed corms, and unwashed corms during curing at 30 °C and storage at 25 °C.

Curing temperatures (30°C) reduced respiratory activity of corms with a strong but not significant (P > 0,05) effect in presence of NaOCl, as opposed to the relatively reduced respiration intensity during the same period of time recorded in water washed and unwashed corms stored at 25°C (Fig. 2). In absence of curing, significant (P<0,05) higher respiration rates could still be observed after 7 days and 15 days storage, on water washed corms (10,3ml CO_2/kg/hr and 4,2 ml CO_2/kg/hr) and unwashed corms (14,8mlCO_2/kg/hr and 5,1mCO_2/kg/hr) (Table1). Contrarily, chlorinated water washing has produced a significant (P<0,05) and satisfactory reduction in respiration intensity after these storage elapsed times (7,3 ml CO_2/kg/hr and 3.6 mlCO_2/kg/hr) (Table 1). In addition, a low and stabilized respiration rate level was obtained faster when curing was used (Fig.2).

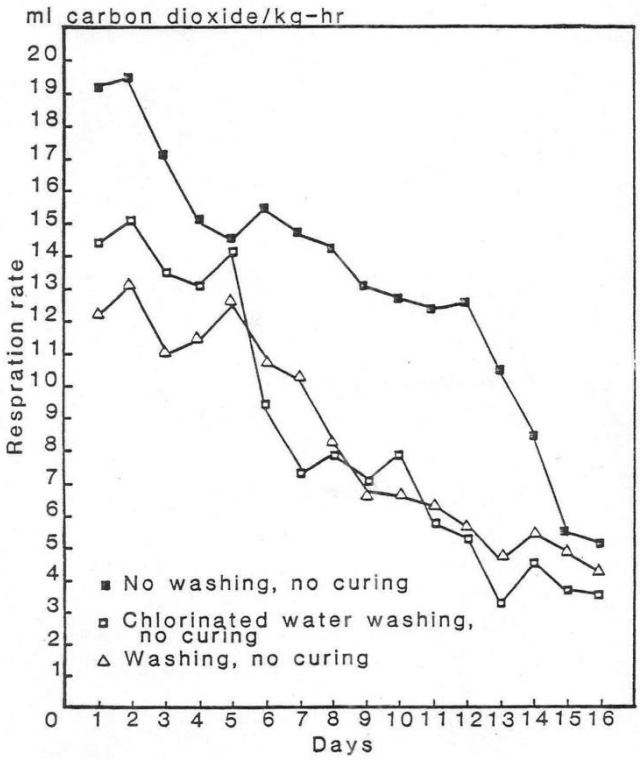

Figure 2 Respiration rates of chlorinated or non-chlorinated or water washed corms and unwashed corms during storage at 25 °C.

Respiration activity and ethylene production were significantly (P < 0,05) affected by curing and injury infliction (Table 2). While respiration rate declined overtime in control corms, bruised corms exhibited higher respiration rates which were detected 6 hours after injury infliction. Following a short decline observed during the second day, additional days in storage brought increased respiratory activity in damaged corms (Fig.3-A). When damage was not inflicted, a continuous and slow drop was recorded in respiration of both cured and uncured corms, the stabilization level (4 ml $C0_2$/kg/hr) of which was suspected after 10 days of storage (Fig. 3-B). Injuries inflicted to corms after 7 days storage also caused corm respiration to rise but not as significantly (P > 0,05) higher levels as in corms damaged immediately

after harvest (table 2). Additionally, this increase was more rapid in uncured corms.

Table 2 Effect of bruising on respiration and ethylene production of cured and uncured cocoyam corms, after 3 days of storage.

Treatment	Respiration rates (ml $CO_2kg^{-1}hr^{-1}$)	Ethylene product (µl $C_2H_4kg^{-1}hr^{-1}$)
Initial curing		
Damage after curing	16,6 b[y]	0,2 b
No damage after curing	06,2 a[z]	0,0 a
No curing, damage	17,9 b	0,6 c
After 7 day of curing		
Control	08,2 a	0,0 a
No initial curing		
Initial damage	37,9 b	0,6 b
Control	05,9 a	0,1 a

y data are means of 3 observations

z means within treatment not followed by the same letter are significantly different at 5% level by Duncan's multiple range test.

Ethylene production was nearly undetectable in control corms throughout the storage period (Fig.4-A). Shortly after they were damaged (6 hours), however, they started to produce ethylene at a low rate which dramatically increased in the following days. Responses in ethylene production showed almost the same pattern when cured corms were injured after 7 days of storage, with less ethylene released when corms were previously cured (Fig. 4-B).

4. DISCUSSION

The high respiration rate recorded in freshly harvested and untreated corms is probably attributable to the relatively intense physiological activity in corn tissue immediately following harvest, resulting from the stressing impact of detachment from the mother plant and the field heat (Burton, 1982). For the 3 replicated samples followed, respiratory activity exhibited the same gradual declining intensity with increasing storage time, typical of non-climacteric tissue (Ryall and Lipton, 1979; Burton, 1982).

It is questionable whether the higher respiration observed in unwashed and non-cured corms was related to the absence of curing and chlorination. In fact since cut ends were not currently healed and decay organisms and adhering soil not eradicated on corms without curing and chlorination respectively, these factors might have contributed to the increased respiratory activity in this treatment.

Water washing dip is helpful in removing soil and dirt and thus a large portion of soil borne pathogens, susceptible of decay infection and contribution to respiration increase in corms. However, the bactericide capacity of chlorinated water washing, which were tested at the recommended level (Bikomo, 2013), might have neutralized potential remaining rotting organisms involved in decay infection on corms and prevent their implication to harmful increase of respiration and ethylene production (Booth, 1978; Ugwuoke et al., 2008; Olayemi et al., 2012; Eze et al;, 2013). Besides, chlorine has been reported to stimulate wounding healing in potato tubers (Crigg and Chase, 1967) and cocoyam corms (Bikomo, 1988; Bikomo and Brecht, 1991).

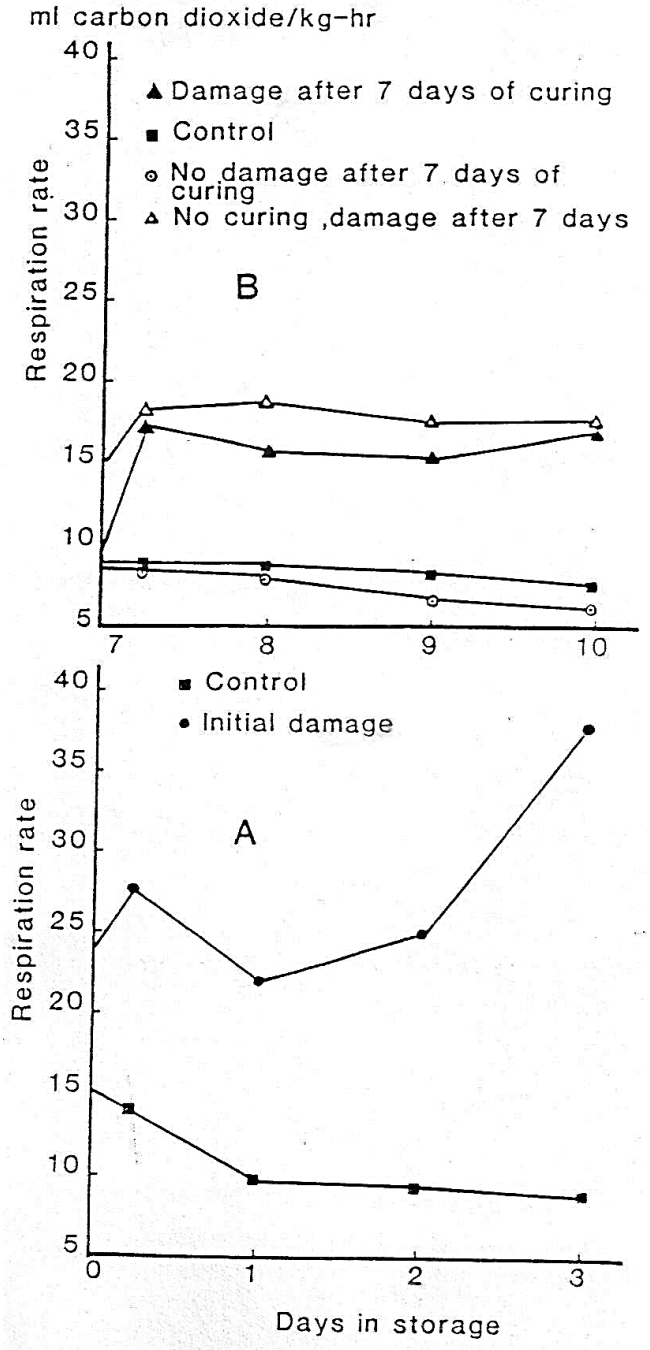

Figure 3 Influence of mechanical damage on respiration of cured and uncured Xanthosoma corms.

The increased that developed after a short decline of the infliction induced high respiration rate of bruised

corms was due to decay which effectively became visible with time spent in storage (Agbor-Egbe and Rickard, 1990; Bikomo, 2013; Eze et al., 2013).

The respiration rate of stored *Xanthosoma* corms dropped progressively following harvest. It reached and stabilized at a low level of about 4 ml of carbon dioxide per kilogram per hour within 2 weeks, compatible with long shelf life duration. A respiration pattern of this type is a normal characteristic of potentially storage commodities, when adequate environmental storage conditions are provided (Agbor-Egbe and Rickard, 1990; Ugwuoke et al., 2008; Addisu et al., 2014). Curing corms at 30 °C with 95% RH before storage was particularly effective in lowering the respiration rate of corms during the storage period. But care must be taken that sprouting is not favored during curing, otherwise, respiration would be intensively activated.

Visible decay symptoms developed on injured corms tissues, and then expanded to the whole corm. Therefore bruising accelerated corm deterioration both by enhancing respiration and allowing pathogen invasion of the issue. Increased respiration such as that detected in these corms is accompanied by increased reserve materiel degradation and is obviously induced by bruising. Dropping potato tubers from a height of 1m into a wooden floor inflicted injury on production was followed by 30-50% increase in respiration over a period of a few days (Burton, 1982).

Results obtained here indicate that the metabolic processes involved in respiration, already attenuated with the time spent in storage, become less susceptible to injuries over time

Ethylene production rates rose to level as high as in corms damaged immediately after harvest, while remaining very low in corms not injured, which suggests that cocoyam should be ranged among naturally non ethylene producing crops (Paull and Ching, 2015). However, ethylene production by cured corms as initially observed, was somewhat less affected by damage compare to uncured corms and was significantly($P<0,05$) lower after 3 days, as a result, certainly, of the effectiveness of the healing, through curing treatment, of the corm injuries involved in ethylene production increase (Bikomo, 1988; Bikomo and Brecht, 1991). Appearance of increased ethylene production was also associated with decay at the site of damages to the corms (Paull and Ching, 2015). Since decay was observed on injured tissues, part of the high respiration and ethylene production might have been contributed by metabolic activities of the microorganisms involved in decay attacks (Agbor-Egbe and Rickard, 1991; Bikomo, 2013; Eze and Amadi, 2013; Paull and Ching, 2015).

The considerable and expected reduction of respiration and ethylene production obtained with combined chlorination and curing treatments indicate the efficiency of adequate level combination of those potentially effective postharvest practices to ensure quality and durable storage of cocoyam corms.

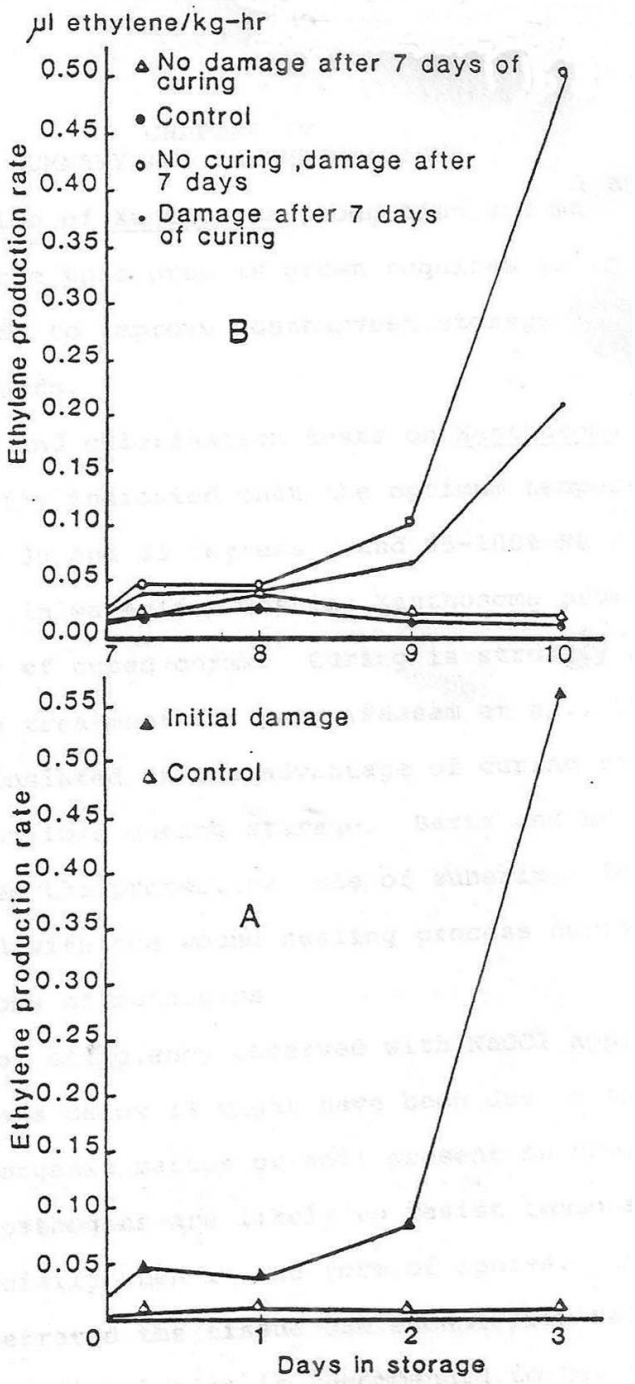

Figure 4 Influence of mechanical damage on ethylene production on Xanthosoma corms.

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