# THE INFLUENCE OF CONTROLLED ATMOSPHERE STORAGE (CA) ON THE DIFFERENCES IN PLASTID STRUCTURE IN THE WARE POTATO 'CARA'

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## ABSTRACT

Driven by UK retailers' demands to extend seasons in conjunction with the reduction of postharvest chemicals in fresh produce, controlled atmosphere (CA) storage in potatoes has proven to be an effective alternative to the use of sprout suppressants such as chlorpropham (CIPC) as being used in conventional cold storage. 'Cara' was stored in air and under CA at 4°C from November 1997. Sections from dormant and developing eyes were taken in April 1998 to identify an initial trend in ultrastructural differences between conventional cold storage and under CA. The main finding was the difference in the plastid structure in the meristematic area. The amount of starch was reduced under CA conditions and the structure of the plastids is radically different. Under cold storage, plastids contain numerous round shaped starch grains, and additionally accumulations of material that are an extremely dense lipo-protein complex.

## INTRODUCTION

The main ware potatoes grown in the UK are 'Maris Piper', 'Cara', 'King Edward' and 'Desiree'. The season can be extended until June in the following year with the use of CIPC or controlled atmosphere (CA) storage which both prevent potatoes from breaking the dormancy resulting in sprout growth. The need to reduce the application of postharvest chemicals in fresh produce as demanded by end consumers and the retailers, forces UK ware potato suppliers to look for alternatives to CIPC for long-term storage, such as the use of controlled atmosphere storage. Concerns such as higher operational costs and uncertainty in terms of changes in taste and texture under CA conditions have led this research to investigate the underlying processes in cell structures under different storage regimes in a commercial trial. The aim of this study was to determine the differences in the ultrastructure of meristematic cells of potato eyes in 'Cara'.

## MATERIALS AND METHODS

The cultivar 'Cara' was stored in air (21:0) and CA (13:6) at 4°C after curing in the UK from November 1997. Samples from dormant and

developing eyes were taken in April 1998 and processed for Light Microscopy (LM), Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM).

Samples were taken from two tubers per treatment. All were fixed in 3% glutaraldehyde in 0.1M Sorensens phospate buffer pH7. For SEM, samples were dehydrated through an acetone series and critically point dried. For Light Microscopy and TEM, samples were secondarily fixed in 1% osmium tetroxide in the same buffer and after dehydration in acetone, they were embedded in epon-araldite before sectioning. Two micrometer sections for LM were stained with 1% toluidine blue in 1% sodium tetraborate. SEM samples were sputter coated with gold before examination. 70-80 nm ultrathin sections for TEM were stained with 4.5% uranyl acetate in 50% ethanol, followed by Reynold's lead citrate (Reynolds, 1963). An Hitachi H7000 TEM was used to examine the sections (75kV).

## RESULTS

The results indicate that the biochemistry in the cells is different under conventional cold storage compared with CA. The main finding was the difference in the plastid structure in the meristematic area from the apical dome of dormant and developing eyes (starting to sprout).

Under cold storage, plastids contain numerous round shaped starch grains, and additionally accumulations of material that are an extremely dense lipo-protein complex, the remnants of membrane structures. Figure 1 shows a meristematic cell of a dormant eye (TEM). Note particularly the plastids with large electron dense inclusions and multiple starch grains, scattered endoplasmic reticulum and dictyosomes. Figure 2 gives a detail of a plastid of a dormant eye with a starch grain, dense body, plastoglobuli and patchy matrix. The plastids of a meristematic cell of a developing eye are small and basic, and only indicate protein and some starch grains (Figure 3).

The amount of starch was reduced under CA conditions and the structure of the plastids is radically different. In a meristematic cell of a dormant eye, the plastid contents consist of lipids and protein (figure 4). The cell contents of a meristematic cell of a developing eye show plastids with minimal content (starch hydrolysis), i.e. no starch and no protein bodies are present. The endoplasmic reticulum frequently exhibits a characteristic form comprising concentric rings (figure 5).

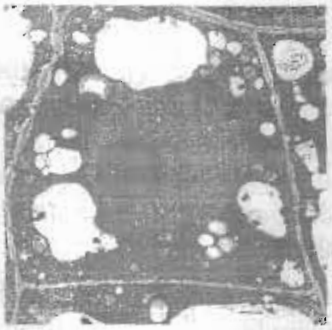

Figure 1: TEM of a meristematic cell from the apical dome of a dormant eye, stored in air at 4°C (scale bar equals 1 µm)

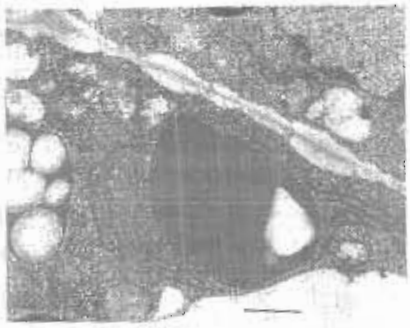

Figure 2: TEM of a meristematic cell from the apical dome of a dormant eye, detail of a plastid, stored in air at 4°C (scale bar equals 1 µm)

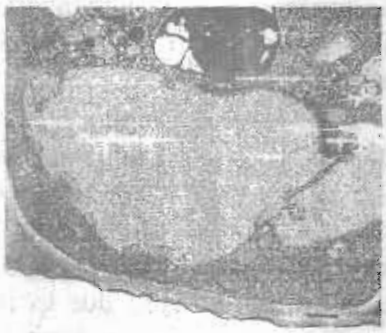

Figure 3: TEM of a meristematic cell from the apical dome of a developing eye, stored in air at 4°C (scale bar equals 1 µm)

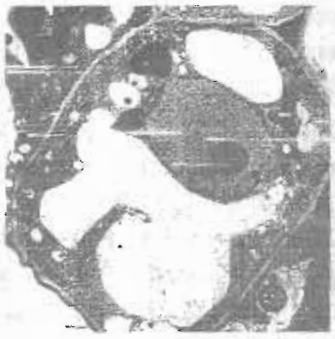

Figure 4: TEM of a meristematic cell from the apical dome of a dormant eye, stored under CA at 4°C (scale bar equals 1 µm)

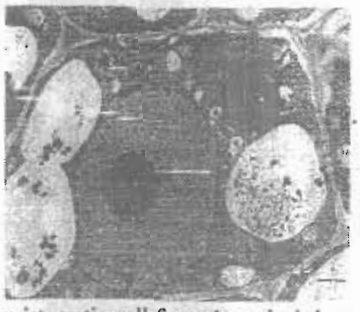

Figure 5: TEM of a meristematic cell from the apical dome of a developing eye, stored under CA at 4°C (scale bar equals 1 µm)

## DISCUSSION

In order to extend the season of ware potatoes, the choice of storage conditions is crucial, as UK retailers have zero tolerance towards tuber sprouting during shelf life in supermarkets whilst aiming to eliminate the use of postharvest chemicals. To avoid sprouting, the breaking of dormancy and/or the breakdown of starch and the production of sugars have to be delayed. This can be achieved by the use of either CIPC or CA.

Starch breaks down into sucrose at low temperature (Isherwood, 1973) due to gibberellin initiated production of ∝-amylase. After conventional cold storage, the process of starch hydrolysis is reversed at 10°C and sucrose is reduced during starch synthesis. The interconversion of starch from sucrose at re-conditioning can be related to the increased respiration of the tubers under these conditions. The control of the starch-sucrose balance is linked to the complex of enzymes governing the carbohydrate interchange, however, temperature does not appear to affect the activity of the isolated insoluble starch synthetase (Isherwood, 1973).

Under CA conditions, the starch hydrolysis was higher and consequently more sugars are produced. Due to the absence of a sink (=sprouts), the sugars remain in the tuber. In previous taste tests, potatoes from CA conditions were sweeter and had a mealy texture compared with conventionally stored potatoes. When potatoes are re-conditioned after CA storage at 10°C, there is a negative feedback on the amylase due to the sugars exceeding a critical concentration. Further starch synthesis is prevented and sugars accumulate. The mealy texture is a result of starch hydrolysis.

Earlier studies on starch have shown that it is stored as reserve material in the parenchyma cells and located as starch grains in the cytoplasm of the cell, which is surrounded by a membrane (Badenhuizen, 1969; Rastovski, 1987). During storage, the average starch grain size increases due to a reduction in the number of smaller starch grains, which can be broken down more readily than larger ones (Reeve, 1967). Results of the present study demonstrate a total break down of starch grains following a prolonged period of CA storage.

## CONCLUSIONS

It is important to note that each condition alters several factors in the tubers that are related to taste and texture whilst suppressing visible sprouting. This research study has shown that there are differences in the

meristemic cells of eyes in ware potatoes under different storage conditions and can explain the increased sweetness under CA conditions.

## ACKNOWLEDGEMENTS

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