FINAL REPORT

The Effect of Atmospheric Components in Potato Storage on Tuber Quality Characteristics

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2. SUMMARY

There were three main components to this study:

- Understanding the range of carbon dioxide levels within working potato stores over a storage season
- Defining the effects of carbon dioxide and ethylene on taste and texture attributes of potato tubers
- Investigating the potential effects of high carbon dioxide concentrations on disease risk in stored tubers.

A summary of the methods and main conclusions for each component are presented below:

2.1. Commercial store surveillance of carbon dioxide levels

Thirteen stores, generally typical of those in general use for pre-pack storage, were assessed for carbon dioxide levels over one season and in 2008-9 six stores were continuously monitored for carbon dioxide. Levels found in almost all the stores evaluated were generally below 1% and, in most cases, below 0.5%. However, there was one notable exception which had levels of carbon dioxide ≥1.5% for the majority of one season with a maximum of > 4%, a level that is life-threatening for humans, see carbon dioxide work exposure limits below.

Carbon dioxide level	Exposure limit
>0.5%	8 hours
>1.5%	15 minutes
>4%	Life-threatening

The majority of the stores had no means of introducing fresh air to the building as part of the routine management of the store and such stores should be subject to either monitoring of carbon dioxide or the introduction of a venting system and regime. The store found with levels of carbon dioxide ≥1.5% for the majority of the storage season is very typical of the types of store in general use for pre-pack storage. The study identified that stores which are well sealed, e.g. by using spray foam insulation, need particular attention to prevent build up of carbon dioxide levels to levels for which there are exposure limits.

The levels of carbon dioxide recorded during this study, including that > 4%, had no apparent effects on taste, texture or appearance on the tubers as most were used to supply supermarket contracts for high quality pre-pack potatoes. There was, however, an elevated weight loss (>6%) observed.

There is a legal obligation to ensure human safety and this study indicates that there are occasions where this obligation may be, however unwittingly or unknowingly, not fulfilled. Storage advice would generally recommend the management of carbon dioxide in store at levels as close to ambient as possible by, for example and where appropriate fresh air flushing.

2.2. Store carbon dioxide and ethylene level effects on potato flavour and texture characteristics.

To define the effects of carbon dioxide and ethylene on taste and texture attributes, three cultivars, Maris Piper, Marfona and Estima were exposed to different levels of carbon dioxide atmosphere from ambient to 6% in store. To understand the potential interactions between carbon dioxide and ethylene used for sprout suppression adversely affecting tuber quality, the trials were carried out with and without ethylene at 10 ppm. Two periods of 37 day storage, each relating to early and late stages in a storage season were undertaken.

Following the treatments, peeled steamed tubers were assessed for flavour differences by a trained taste panel who detected differences in taste and texture. The differences identified are explained largely by cultivar, with storage duration period and year of the trial also contributing a lesser, but significant, effect. The three cultivars, Maris Piper, Marfona and Estima could clearly be differentiated from each other. The age of the tubers reflected in the time of the storage duration period, January or May, was a significant factor within each trial year. There were also seasonal differences noted over the two years of the trial, with cultivar taste and texture attributes slightly changing from year to year. Carbon dioxide and ethylene were relatively unimportant, overall changes in taste and texture attributable to ethylene and carbon dioxide were very small and inconsistent. There was no finding of an unpleasant attribute associated with either gas.

Previously, anecdotal reports of unwanted ‘off flavours’ were reported for some varieties of pre-pack potatoes (Briddon, 2006). The results of this study do not indicate that carbon dioxide and/or ethylene gases contributed to these off flavours. However, it is possible that there are interactions between potato production and potato storage environment during a particular year, that have not been experienced in the two years of the trial, that can lead to unwanted effects on tuber taste and texture.

2.3. Potato tuber infection by bacterial and fungal pathogens under different carbon dioxide incubation atmospheres.

Altering the carbon dioxide level of the storage atmosphere over the range ambient to 10% within the incubation environment has different effects on different pathogens. Infection with both *Pectobacterium carotovorum* and *Phoma exigua* increases with increasing carbon dioxide concentration whereas infection *Fusarium sulphureum* decreases with increasing carbon dioxide concentration.

2.4. Conclusions

The very high levels of carbon dioxide found in some stores are a significant health hazard and within the scope of regulatory carbon dioxide work exposure limits. Advice is to manage of carbon dioxide in store to keep levels as close to ambient as possible by, for example, the appropriate addition of fresh air through flushing. Users of ethylene might choose to limit flushing to minimise ethylene loss in commercial stores but periodic flushing to control carbon dioxide build up is advisable.

3. PROJECT INTRODUCTION

The GB potato industry is highly reliant on refrigerated storage to serve its markets' needs throughout the year for high quality, blemish-free potatoes with low chemical residues. Levy payers have questioned, for example at the Potato Council Forum on potato storage (2007), the impact of this type of storage and, in particular, the effects of the atmosphere within these types of store, on tuber quality.

Many potato stores are well-sealed units and carbon dioxide levels can be very high and this is an area of concern (Briddon and Jina, 1996). Being well sealed, there is little opportunity for ambient air exchange to take place to remove the products of the respiration process.

Insufficient ambient air exchange is associated with:

1. Taste and texture

Within the potato industry carbon dioxide is thought to be an important factor affecting taste and texture of stored potatoes. Anecdotal claims have been made that elevated carbon dioxide (>10%) can induce "off-odours, off-flavours, internal discolouration, and increased decay" (Suslow and Voss, 2009) and "carbon dioxide, the by-product of respiration and other deleterious gasses, which affect tuber quality" (Small and Pahl, 2005). However, these web pages do not contain further details or cite specific evidence for their statements. There is no current, publically available information demonstrating an effect of carbon dioxide on potato quality other than some contradictory effects on fry quality discussed by Daniels-Lake & Walsh (2005).

Other store atmosphere components are similarly thought to affect quality. For example the use of ethylene as a sprout suppressant was associated with the development of unwanted side-effects on tuber taste and texture. Initially thought to be a direct consequence of ethylene, it is possible that effects are in response to excessive carbon dioxide concentrations (Briddon, 2006). Confidential research into the impact of ethylene on potato quality, funded by Restrain Company Ltd. at Sutton Bridge, indicated that taste and textural changes were associated with carbon dioxide. Subsequently ethylene management and control systems have been modified to minimise store carbon dioxide levels.

Ethylene has a very pronounced stimulatory effect on respiration rate leading to the possibility of elevated carbon dioxide levels. Treatment of potato tubers with ethylene causes a rapid and very large rise in their respiration rate, up to 10 times the rate of untreated tubers over 30 hours of treatment before falling slowly (Reid and Pratt, 1972). However, the use of ethylene offers a major opportunity for residue-free storage and the area of store atmosphere effects on potato quality was identified as requiring further research (Briddon, 2006).

2. Disease development

Diseases and defects are influenced by the store atmosphere. Oxygen depletion and/or carbon dioxide accumulation have been shown to increase the levels of disease development (Powelson and Franc, 2001) or to be associated with non-pathogenic disorders in store (Briddon, 2006).

Problems such as soft rot which, in the presence of moisture, can rapidly lead to tuber breakdown in anaerobic conditions (Pérombelon, 2002) and disorders, such as blackheart and pit rot previously associated with field clamp storage (Anon, 2001), have been reported in recent years in problematic crops and anecdotally linked to well-sealed stores (eg Storage Advice Line, Sutton Bridge CSR).

Whether carbon dioxide is affecting taste and texture or levels of diseases and disorders – or both – the consequences of any such influence on tuber quality on the commercial saleability of a crop can be disastrous for producers. However, there is very little data available in the public domain detailing either the changes in this significant component of the store atmosphere or its consequences. As a current advert for a storage CO_2 sensor asks "what level of CO_2 is critical for potato quality?" (http://www.techmark-inc.com/pdf/vfdco2.pdf), the answer to this question is highly valid and topical.

This project will aim to investigate the changes in carbon dioxide that take place within the atmosphere of a potato store and the consequences for crops held within it.

4. COMMERCIAL STORE SURVEILLANCE OF CARBON DIOXIDE LEVELS

4.1. Introduction

Work conducted at Sutton Bridge in the mid-1990s (Briddon & Jina 1996, Anon. 1997) found levels of carbon dioxide at levels approaching 4% in commercial processing stores. As a result of that and other work focused on improving the quality of the store atmosphere, recommendations were changed to encourage the routine venting of processing stores to optimise frying quality. Pre-pack stores are typically well sealed to minimise energy costs and the risks of condensation and there is a need to understand the implications of carbon dioxide build up in relation to tuber quality.

This component of the study was designed to assess carbon dioxide levels occurring as part of current normal management practice in a range of commercial pre-pack potato storage buildings.

4.2. Material and methods

4.2.1. 2007-08

Carbon dioxide was measured at approximately monthly intervals during the storage season in 13 refrigerated box stores, listed in Table 3.1. In three stores A, B, and D, highlighted in Table 3.1, carbon dioxide was continuous monitored with Vaisala Carbocap GM70 carbon dioxide meters. Temperature and air pressure was adjusted for the prevailing initial conditions and data was logged at 15 minute intervals.

A common crop of Marfona was used to carry out measurements in stores A, B, and D for respiration rate, diseases, defects, sprouting and weight loss. Ten Marfona tubers in an air-tight plastic container were placed in each store and the carbon dioxide level was measured, at intervals over the storage season, by aspirated flow over a Vaisala carbon dioxide meter. Following the measurement the lid was removed to allow tubers access to store atmosphere. Sample nets of crop containing a known weight, approximately 10kg tubers, loaded into randomly allocated boxes within the store, were recovered at store unloading and re-weighed.

Store	Tonnes	Temperature (°C)	Sealing score: Well-sealed (1) - v leaky (5)	Fresh air flush/bleed?	Ethylene used?
A	**1100**	**3**	**3**	**No**	**Yes**
B	**1600**	**3**	**2**	**No**	**No**
C	850	2.5	1	No	No
D	**1150**	**2.5**	**2**	**No**	**No**
E	1600	3	1	Yes: 5min/24h	Yes
F	1050	2.5-3	1	Yes	Yes
G	1000	3	2	No	No
H	1500	2.6	3	Yes	No
I	1600	3	2	Yes	No
J	1000	3-3.5	2	Yes: 1/week	No
K	1450	2.5	1	No	No
L	850	2.5-3	3	No	No
M	1350	2.5-3	2	No	No

Highlighted stores (A, B & D) subject of continuous monitoring

TABLE 3.1: REFRIGERATED BOX STORE CHARACTERISTICS AND MANAGEMENT

4.2.2. 2008-9

In 2008-09 carbon dioxide was continuously monitored in six stores (Table 3.2) using the Vaisala equipment described above. Measurements were recorded at 15 minute intervals when loggers were present. Loggers were not able to be placed in all six stores at the same time.

Store code	Tonnes	Temperature °C	Sealing score: well-sealed(1) / v leaky(5)	Fresh air flush/bleed?
B	1600	3	2	Yes
D	1150	2.5	2	No
N	1200	3	3	Yes
P	450	3	3	Yes
S	450	3	3	Yes
T	1100	3	3	Yes

TABLE 3.2: 2008-09 REFRIGERATED BOX STORE CHARACTERISTICS AND MANAGEMENT

4.3. Results

4.3.1. 2007-08

Data from spot readings of carbon dioxide levels for the 13 stores are shown in Figure 3.1 and continuously logged values for Stores A, B and D are shown in Figure 3.2. Levels of carbon dioxide of up to 4% were measured in store B. The levels were very variable especially earlier in the storage season. Levels of carbon dioxide in stores A and D seldom exceeded 0.5%.

Tuber respiration rate data for stores A, B and D are shown in Figure 3.3. The use of ethylene in early November resulted in a relatively short but significant (~4-fold) rise in respiration rate in store A. The solid line, Figure 3.3 (i) appears to suggest a slow build up prior to this date. However, this is likely to be due to the absence of baseline data as the respiration rate falls to a more stable rate for the two measurements late in November and December. There is a very noticeable difference in respiration rate between tubers in stores B and D. An initial high respiration level in store B gradually declined over four months before rising slightly as storage duration extended. Tubers in store D had a low and stable respiration rate, less than 2 ppm CO2/kg/min, also rising slightly as storage duration extended.

Weight loss data for sample nets removed from stores A, B and D are shown in Figure 3.4. Those from store B showed a significantly higher weight loss (in excess of 6%) compared with the other two stores (<3%).

No significant effects were found for the effect of store atmosphere on levels of disease, defect, or sprouting in the common crop material from any of the stores.

4.3.2. 2008-09

Data from monitoring of carbon dioxide levels for the individual six stores are shown in Figure 3.5. Levels of carbon dioxide of over 1% were measured in stores D and occasionally in store B whereas levels in stores N, P, S and T seldom exceeded 0.5%.

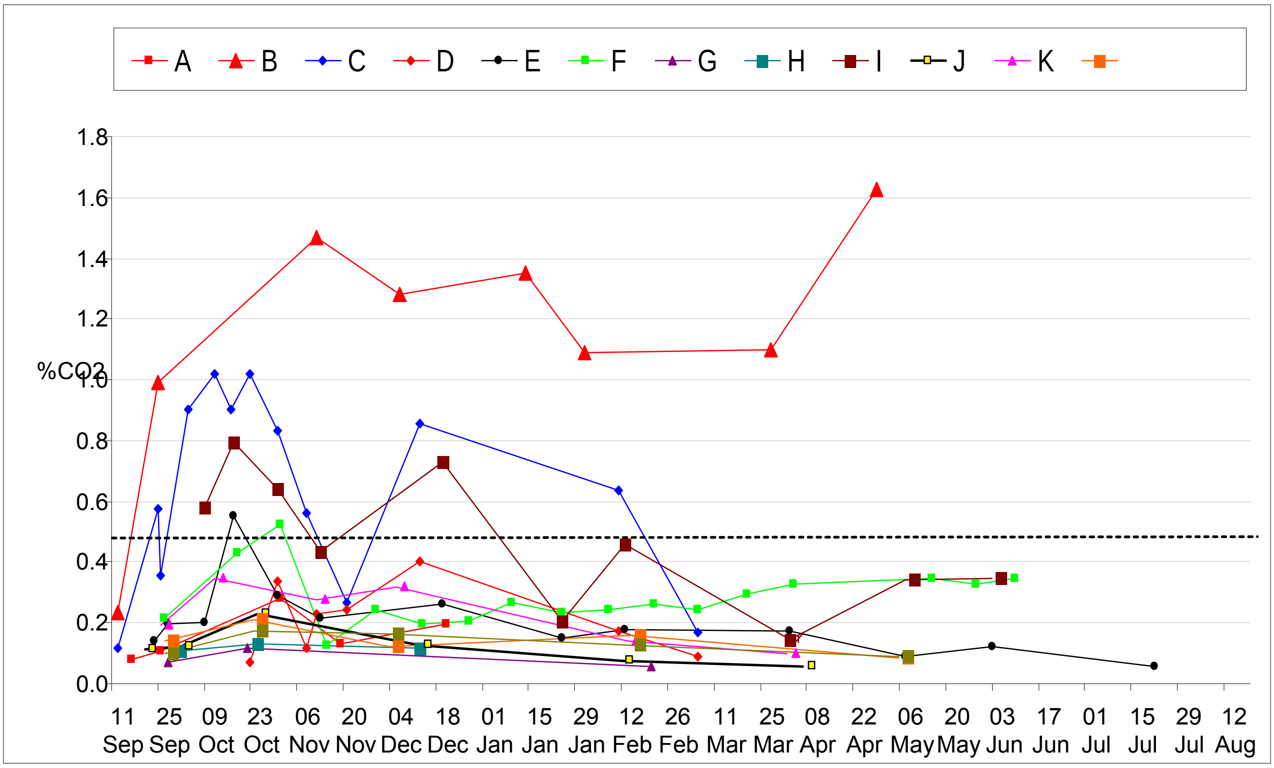


FIGURE 3.1 SPOT READINGS OF CARBON DIOXIDE LEVELS IN 13 COMMERCIAL STORES, SEASON 2007/08

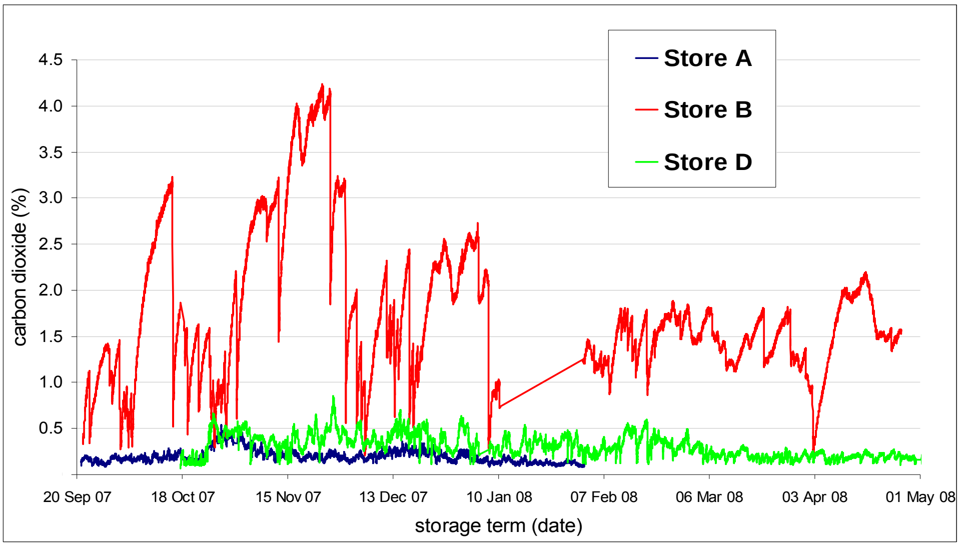
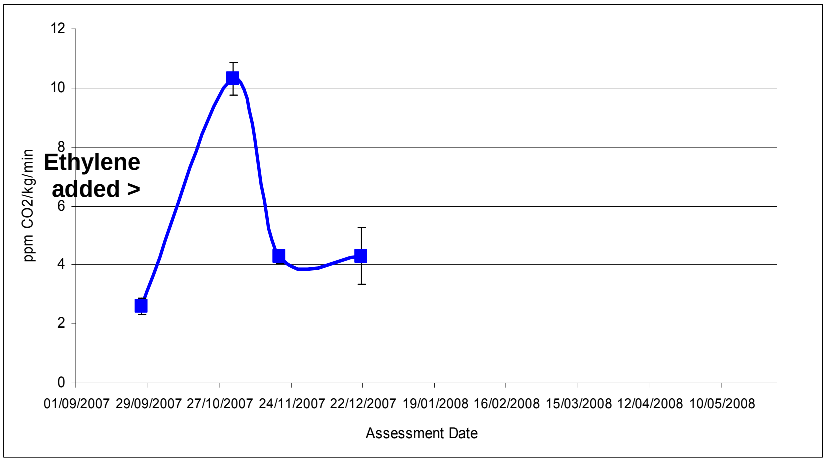
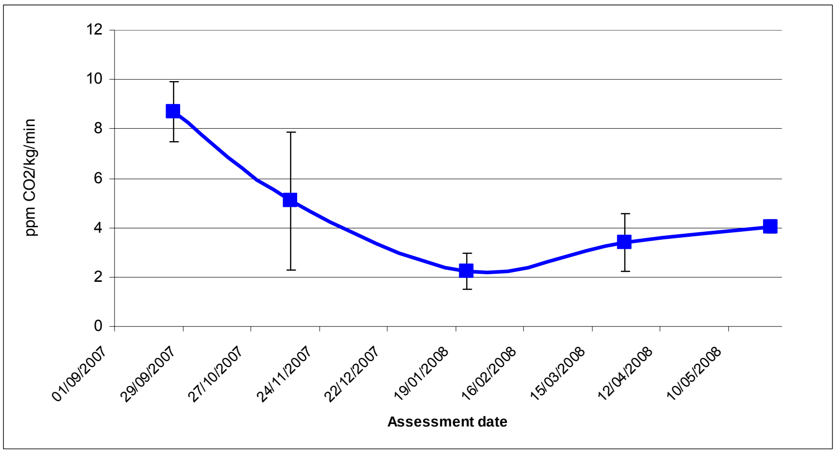


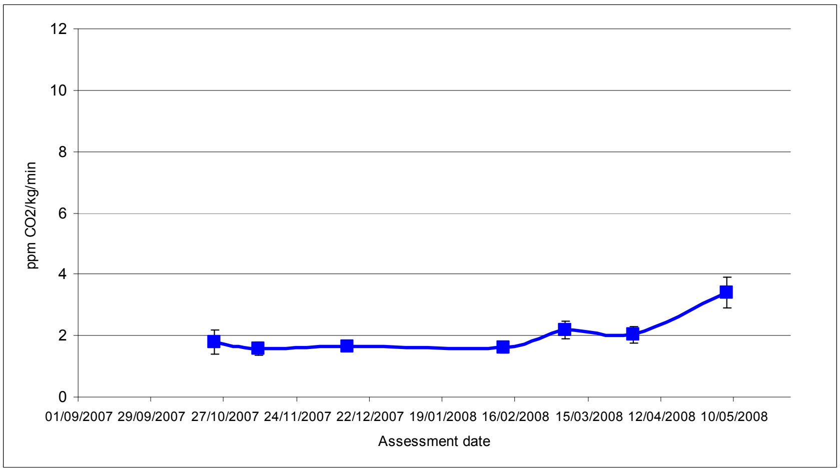
FIGURE 3.2: CONTINUOUS ASSESSMENT OF CARBON DIOXIDE FROM STORES A, B AND D, SEASON 2007/08



(i)



(ii)



(iii)

FIGURE 3.3: SPOT RESPIRATION RATE MEASUREMENTS FOR (I) STORE A (II) STORE B AND (III) STORE D, FOR SEASON 2007-08

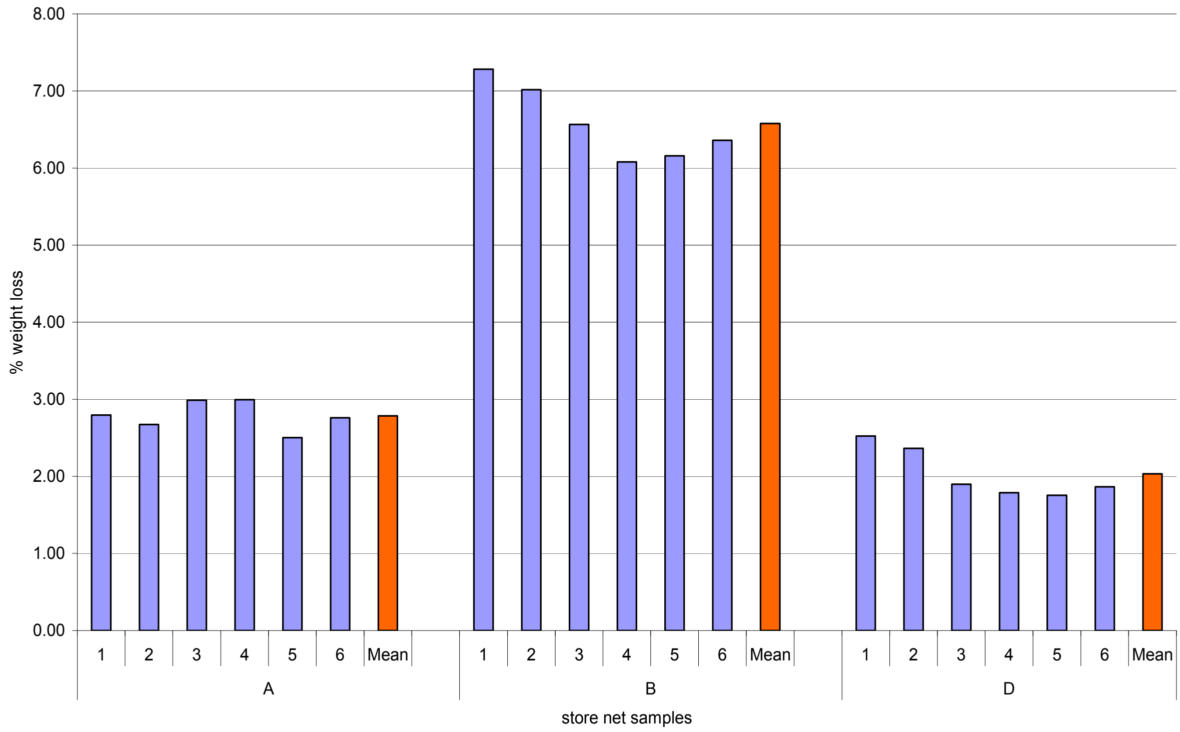


FIGURE 3.4.WEIGHT LOSS (%) IN NETTED SAMPLES OF MARFONA HELD IN STORES A, B & D, SEASON 2007-08.

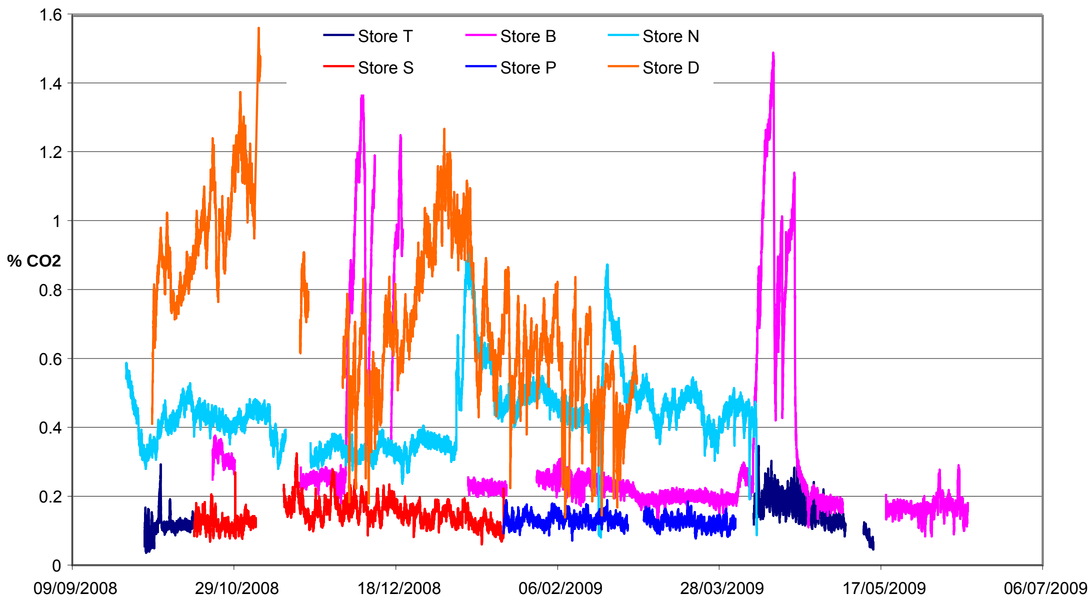


FIGURE 3.5: CONTINUOUS ASSESSMENT OF CARBON DIOXIDE OF STORES, SEASON 2008-09 .

4.4. Discussion

The stores monitored in this study are very typical of the types of store in general use for pre-pack storage with the majority having no means of introducing fresh air to the building as part of the routine management of the store. Generally the levels of carbon dioxide measured during the season show that, with one notable exception, the levels were generally below 1% and, in most cases, below 0.5% across all the stores surveyed.

The exception, store B, had very high levels of carbon dioxide, during 2007-08 with an average of 1.5 % for the majority of the season and occasional levels of over 4%. These levels are subject to workplace exposure limits with the higher levels being life-threatening for human beings (Table 3.3). These consistently high levels are commensurate with the findings in earlier work[2]. The reasons for this level of accumulation are difficult to discern. The store is a conventional metal clad structure insulated with spray-foam which tends to seal the building well. However, the store could not be described as air-tight as there are clear visible areas for potential leakage around the door, for example. Nevertheless, without any way of displacing the air i.e. an inlet and an exit route for air movement, this won't necessarily result in air exchange.

Following problems with carbon dioxide build-up in 2006-07 (not reported here) and 2007-08, this store was fitted with a fresh air exchange flush system during summer 2008. This resulted in much lower levels of carbon dioxide during 2008-09. However, the store is still subject to sharp rises in carbon dioxide concentration if the fresh air system is turned off, as was the case during in April 2009 where there is a sharp spike seen in Figure 3.5.

During 2007-08 in stores C and I levels of up to 1% carbon dioxide were measured. The former was an old brick built building which had been very well sealed with spray-foam, whilst the latter was a more modern, high specification composite panel store.

Carbon dioxide level	Exposure limit
>0.5%	8 hours
>1.5%	15 minutes
> 4%	Life-threatening

TABLE 3.3: CARBON DIOXIDE WORK EXPOSURE LIMITS[3]

Of the six stores assessed, most have some means of introducing fresh air to the building as part of the routine management of the store, although this was not always utilized to a great extent.

During 2008-09 levels of carbon dioxide in store D were found to be quite consistently high (over 0.5%) reaching in excess of 1% at times during the season (Figure 3.5) again levels which are subject to an exposure limit for human beings. This store has no fresh air facility. The reasons for these higher accumulations are again difficult to pinpoint, but the store is insulated with spray-foam which tends to seal the building well, and dispersal of the products of respiration is not easy to achieve without mechanical assistance.

These stores are very typical of the types of store in general use for pre-pack storage and the readings of carbon dioxide taken across the season show that levels in stores which are well sealed, e.g. by using spray foam insulation, need to be checked. Frequent venting with fresh air, may be required to minimize any impact on the crop and those working in the building. However, to avoid problems with condensation, any introduction of fresh air needs to be done in a controlled manner with due attention paid to dew point. Further, there is a legal obligation to ensure human safety and this study indicates that there are occasions where this obligation may be, unwittingly, not fulfilled.

The high level of weight loss (>6%) measured during 2007-08 in samples placed in store B perhaps over-estimate the true weight loss because the samples were held in crates on the periphery of the store. However, the samples do indicate that the level of weight loss was much higher than in, for example, Store D, which was unloaded at a similar time (Figure 3.4). This weight loss may be accounted for in part because of the increased respiration rate measured in store B compared to that observed in store D. Previous trials (Briddon and Jina 1996) have shown higher weight loss can be expected in high carbon dioxide environments. There are several other factors which can contribute to weight loss including store humidity, fridge running times and air circulation paths within the store.

There is a relationship between tuber respiration rate and increased levels of carbon dioxide or reduced levels of oxygen. Two early studies reported a decrease in respiration in relation to increased carbon dioxide or to reduced oxygen levels. High (5-7%) carbon dioxide levels reduced respiration by 25-30% (Burton,1952) and, at 20°C, reduced oxygen levels reduced respiration gradually and almost linearly until very low levels (~3%) of oxygen (Mapson and Burton 1962). However, in contrast Perez-Trejo et al. (1981) demonstrated that high concentrations of CO2 applied to whole tubers stimulated a rapid and pronounced respiratory gas exchange, which persisted for a prolonged time. The upsurge in respiration was proportional to the applied CO2 concentrations. Previous trials at Sutton Bridge on processing crops (Briddon and Jina 1996) identified a profound effect on the quality of stored tubers with high levels of carbon dioxide (3% for six weeks, 0.5% for a further six weeks and 3% for a further four weeks) significantly increasing fry colour. It is unclear whether the increased levels of reducing sugars were a direct consequence to a storage stress or, in contrast to the earlier studies of Burton and co-workers, an effect of carbon dioxide increasing respiration.

Discussions with the managers of store B suggested that there were no apparent effects of high level of carbon dioxide exposure to the crops removed from the store. Most have been used to supply supermarket contracts for high quality pre-pack potatoes with no adverse comments reported. It is possible that small increases in reducing sugars are of less importance for the pre-pack market compared with the processing sector and do not translate into differences in tuber quality.

4.5. Conclusions

The majority of pre-pack stores included in this study adequately control carbon dioxide build up. However, some stores showed very significant levels of carbon dioxide, enough to compromise worker health and safety and within the scope of regulatory carbon dioxide work exposure limits. Given the serious consequences of these levels, the message of monitoring and control of carbon dioxide in stores should be clearly made. Monitoring or assessment of carbon dioxide levels can be included as part of store management.

Carbon dioxide build up can be mitigated by the inclusion of a regular fresh air flushing regime, manual or automated. Manual systems are at risk of creating condensation. However, the correct use of automated systems is also important as sharp rises in carbon dioxide concentration can occur if the fresh air system is turned off, as observed in this study.

Although it is not clear precisely why particular stores are prone to the problem, those with spray-foam insulation appear to be more susceptible to carbon dioxide build-up and it is likely to be a function of reduced passive air exchange.

There is no evidence of a deleterious or detrimental effect on the quality of the potato exposed even to very high levels of carbon dioxide in this particular study. No effects on disease, defect or sprouting behaviour were found and hearsay evidence suggests that the tubers were of marketable quality.

Weight loss of tubers exposed to high levels of carbon dioxide was increased, however whether this is a direct or associated effect or the consequence of air movement through the store is unknown.

The relationship between the respiration rate and levels of carbon dioxide or reduced levels of oxygen has not been investigated with respect to current varieties and storage conditions. Possible consequences including weight loss, and possibly tuber quality, could be readily identified from either sampling from commercial stores or from controlled atmosphere work.

5. Store atmosphere effects on potato flavour and texture characteristics

5.1. Introduction

A previous study, Briddon & Jina (1996), has shown that, in some potato stores, carbon dioxide can accumulate to levels hazardous to health. Despite no clear documented relationship between such levels and deleterious changes in tuber quality, there has been concern that, on occasions, an interaction between carbon dioxide and other atmospheric treatments used for sprout suppression, notably ethylene, can adversely affect potato quality.

The use of ethylene for potato sprout control was reviewed in 2006 (Briddon). The review also summarised the available information on the other attributes associated with the use of ethylene, and included anecdotal reports of adverse effects of ethylene treatment on the taste and texture of some crops. These occurred during the 2004/5 storage season when the use of ethylene in some stores was associated with an increase in the firmness/waxiness of some crops of cvs King Edward and Maris Piper and the development of a “nutty” flavour in cv Marfona. It was suggested that the changes in quality could have been the result of high carbon dioxide levels, possibly as a result of a stimulation in respiratory activity resulting from the introduction of ethylene, or that the effects may have been the result of store construction/management.

On the occasions where the potential for store atmospheres to affect potato quality was suggested, adverse affects had occurred within a short period of loading. The experiments described here, carried out over two storage seasons, attempted to mimic those occasions by conducting short-duration exposure trials in which tubers were subjected to a range of store atmospheres either early or late in the storage season.

5.2. Material and methods

Experimental work was carried out to assess the importance of store carbon dioxide or ethylene levels on the flavour and texture characteristics of the cultivars Marfona and Maris Piper, both considered sensitive to CO_2/ethylene damage and cv. Estima considered insensitive

5.2.1. Year 1, 2007-08

Samples of the three cultivars were held under controlled atmosphere conditions in 0.75m^3 chambers at 3.5°C with carbon dioxide maintained at 0.5%, 1.5%, 3.0%, 4.5% and 6.0%. In separate chambers, each carbon dioxide concentration was maintained with and without the addition of ethylene. Ethylene was manually injected once every 24 hours to achieve a target concentration of 10 ppm. High relative humidity was maintained by means of a tray of water in the bottom of each chamber. Exposure to controlled atmospheres was carried out in two phases of 38 days starting on 31st October 2007 and 6th May 2008 representing short and medium/long term storage respectively. After phase 1, selected sub-samples were delivered to Leatherhead Food International (LFI) for the development of a descriptive vocabulary. The full sample set, for formal assessment was delivered on 7th January 2008. Interim storage of samples, between vocabulary development and formal assessment, was at 3.5°C. Phase 2 samples were delivered to LFI on 16th June 2008, two days after controlled atmosphere was discontinued.

5.2.2. Year 2, 2008-09

Following the results of the first year trial it was concluded that a simplified trial would prove informative and be more manageable in terms of atmosphere control. Consequently three carbon dioxide concentrations were used in the second year, and fewer tubers, sufficient for LFI assessment, were stored in each CA chamber to minimise the impact of crop respiration on atmosphere control.

Tuber samples of the three cultivars were held under controlled atmosphere conditions in 0.75m^3 chambers at 3.5°C. In separate chambers, carbon dioxide concentration was maintained at ambient, 1.5%, and 4.5% with and without the addition of ethylene at 10ppm. Ethylene was manually injected once every 24 hours to achieve the target concentration. Exposure to controlled atmospheres was carried out in two phases of 37 days starting on 9th December 2008 and 5th May 2009 representing short and medium/long term storage respectively. After each of phase 1 and phase 2 the sample sets were delivered to LFI for formal assessment on 19th January 2009 and 15th June 2009, respectively.

5.2.3. Leatherhead Food International (LFI), taste and texture assessments 2007-2009

5.2.3.1. Sample preparation

Potatoes were washed, peeled, rinsed and then cut into pieces. Portions achieved from each potato was dependent on the potato size, small potatoes being sliced into two and the large potatoes being cut into six or sometimes eight. The potatoes were cut up as consistently as possible, so that the pieces of potato were as uniform as possible, to enable them to be cooked to the same degree. The portioned potatoes were cooked using Tefal Steam Cuisine Ultra Compact 3-tier steamers, model series S04. The potato pieces were cooked until soft, which was judged by penetration with a sharp knife. Typically the steaming time was 25-30 minutes.

5.2.3.2. Product Profiling and Vocabulary generation and training

A sensory profile was developed in January 2008, based on the principles of quantitative descriptive analysis (QDA), on sub-samples delivered to LFI for this purpose and prepared as above. This profile was developed and produced prior to the formal assessment of samples from the four phases. The final glossary against which the 2008 and 2009 products were scored is detailed in Annex 1. References to clarify particular sensory attributes are shown in Annex 1.
Assessors were drawn from the sensory panel at LFI. All were trained in the sensory evaluation of an extensive range of food and beverage products and were familiarised with the sensory profile for these samples of potatoes prior to the assessment.

5.2.3.3. Sample assessment

All potato samples were tested in triplicate, whereby all assessors evaluated the potatoes three times over three days.

All samples were presented to the assessors directly from the steamers. For practical and consistent presentation of the potatoes, each replicate was divided into ten sessions, each comprising three different potato samples, presented in a balanced presentation order. Over the three replicates each potato variant was seen with six other samples. Each assessor carried out an individual evaluation of all the test samples, each sample evaluated singly in a sequential randomized (year 1) or a balanced presentation (year 2) manner. In year 1, both phases, samples were randomly allocated for evaluation. In year 2 the sample presentation order was altered to improve resolution of treatment effects and each cultivar was assessed separately with one cultivar per day. All assessments were carried out in separate booths at the LFI sensory facility. Assessors used line scales to indicate intensity of attributes. Sensory data was collected using a computerized acquisition system, Compusense 5 v4.8.

5.2.3.4. Data Analysis

The data from each panellist was pooled and analysed to determine the differences between the samples. Univariate analysis, examining each attribute, was carried out using ANOVA and Fisher's least significant difference (LSD) for multiple comparisons between samples. A significance level of 5% (95% confidence) was applied for measurement of statistical significant differences between samples. Additional data analysis was carried out to obtain Tukey's honest significant difference (HSD) as a more conservative method to measure significance differences. Data analysis was carried out using Senpaq version 3.9 and Microsoft® Excel 2002, SP3.

Further analysis to determine the relationship between the samples and the flavour attributes was carried out on pooled the data using Principal Component Analysis (PCA). General Linear Modelling (GLM) was used to identify whether there were interactions between the treatments. Data was analysed for both methods using XLSTAT 2009.2.02. These analyses were carried out and the results interpreted by LFI.

5.3. Results

5.3.1. 2007-08

The complete LFI 2007-08 report of the taste panel assessments is at Annex 1; below is a brief summary of their results.

The results indicate that variety and storage phase have the major effects on taste and texture. The use of ethylene can result in small changes in the organoleptic properties of cooked potatoes. The main change was that of texture, with ethylene use giving rise to a small increase in attributes associated with firmness or reduced flouriness. The effect of carbon dioxide/ethylene in determining overall texture is unclear.

PCA identified the major differences as those between potato varieties, with Marfona and Maris Piper being most distinct. The PCA plots (Annex 1) show that each variety clusters, more or less separately, independently of time of assessment or treatment. Time of assessment identified some differences as all clusters for untreated assessments shift in the same direction within dimension 2 for assessment 2. In comparison with assessment phase 1 there is less separation of the treated from untreated potatoes for both Maris Piper and Estima, the assessment 2 clusters for treated and untreated superimpose.

General linear modelling (GLM) identified some small effects on taste and texture within the assessments with ethylene treatment as having overall less crumbliness and dryness, less sour/bitter and metallic and more sweetness and intensity characteristics.

The level of carbon dioxide seemed to have a very small influence on the differentiation between the potatoes. GLM identified an increase in sweetness in the potatoes stored at the higher levels of carbon dioxide. No significant flavour off-notes were identified for any variety or treatment.

5.3.2. 2008-09

The report and results of the taste panel assessments carried out by LFI during 2009 are reported in Annex 2; below is a brief summary of their results. Table 4.1 summarises the taste and texture attributes in which significant differences were found for each variety for the two storage phases.

	Variety	Estima	Estima	Marfona	Marfona	Maris Piper	Maris Piper
	Assessment phase	**1**	**2**	**1**	**2**	**1**	**2**
	Attribute						
Aroma	Overall aroma intensity						
	Potato						
	Fishy						
	Savoury						
	Earthy	✓					
	Cabbage water						
	Off						
Appearance	Colour						
	Smooth	✓					
	Dry					✓	
	Blemishes				✓		
	Glassiness						
	Blackening / Greying	✓	✓	✓			
	Mottled			✓			
	Surface Disintegrating						
Texture / mouthfeel	Hardness on 1st Cut			✓	✓		
	Hardness on 1st bite			✓		✓	
	Absorbent						
	Waxy	✓		✓			
	Floury			✓		✓	
	Cloying		✓	✓			
	Grainy			✓			
	Breakdown rate	✓	✓	✓			
Flavour	Overall flavour intensity						
	Potato						
	Sweet	✓		✓	✓		
	Fishy						
	Savoury						
	Earthy			✓			
	Sour						
	Bitter						
	Metallic				✓	✓	
	Cabbage water		✓			✓	
	Off						
Aftertaste	Overall aftertaste intensity						
	Potato						
	Sweet	✓	✓	✓			
	Metallic			✓			
	Earthiness			✓			
	Sourness			✓			
	Bitter			✓			
After -feel	Astringent			✓			
	Mouthcoating			✓	✓		
	Irritant						

TABLE 4.1. SUMMARY OF SIGNIFICANT DIFFERENCES FOUND IN ASSESSMENTS OF FLAVOUR ATTRIBUTES FOR ALL VARIETIES AT BOTH ASSESSMENT PERIODS

Overall the significant taste and texture determinants were provided by variety, followed by the storage phase, corresponding to the stored age of the tubers, with these two components accounting for the majority of the differences between samples. Neither ethylene nor carbon dioxide was consistently associated with any significant taste and texture attribute changes. Marfona, the variety most affected by ethylene, was very slightly harder on first cut, less sour in taste and aftertaste and had a less metallic flavour. Effects were more evident in the first phase of the trial.

Some trends of very minor significance were potentially identified for tubers exposed to different CO_2.atmospheres. These were principally for cvs. Marfona and Estima and related to very slight increases in sweetness and sweet after taste and a slight decrease in sour aftertaste. However, these effects were not consistent either between phases of the 2009 trial or between varieties.

PCA indicates that most of the variance of the data was explained by variety and, to a lesser extent, storage phase. The plot (Annex 1) indicated that the potato varieties separated along dimension 1, with Maris Piper situated on the left side of the plot opposite to Estima and Marfona. Dimension 2 appears to be associated with the assessment period, with the samples profiled in January situated at the top of the chart polar to those tested in June.
No simple clustering can be seen for ethylene or carbon dioxide treatments. The ethylene treatment and the carbon dioxide levels on the potatoes appeared to be evenly distributed and are not seen to have a significant effect.

GLM was used to investigate whether interactions between treatment variables occurred. Based on the attribute position on the PCA plots, the raw data was clustered into the eight following groups for analysis of four effects; potato variety, ethylene, carbon dioxide and time.

1. Crumbly/dry
2. Sour/Bitter/Metallic
3. Potato/Earthy
4. Hard/Savoury
5. Sweet/Intense
6. Off Notes
7. Bad Appearance (blemishes & blackening/greying)
8. Aromatic

Results indicated the following:

- The attributes associated with each of the clusters were significantly affected by the potato variety
- Time appeared to affect clusters 2, 4, 5, 6 and 8.
- The results showed that ethylene, had an effect on cluster 8- i.e. bad appearance.

The results appear to show an interaction of time and ethylene, with treated potatoes in the first assessment scoring higher on the attributes contributing to bad appearance, than controls or in the second assessment. Marfona was more affected more than the other varieties.

- Carbon dioxide levels appeared to have an effect on cluster 2 - sour/ bitter/ metallic

5.3.3. Combined years trial results

Prepared by LFI, a comparative analysis and summary report is contained within Annex 3. The major taste and texture differences were between potato varieties. Taste and texture differences were noted between phases of treatment in both years of the trial and there are some year-to-year taste and texture differences within a potato variety. Marfona treated with ethylene shows a slight increase in sweetness attributes in both years otherwise the minor effects identified in 2008 were not replicated in the 2009 trial. There were no consistent or significant effects noted for carbon dioxide treatments

5.3.4. Analysis of influencing factors

LFI provided an analysis and interpretation of the combined PCA data for matched treatments for both years. ANOVA was carried out on the factors (variety, ethylene, carbon dioxide, month and year) for dimension 1- 4 of the PCA plots. The results are shown in Tables 4.2 A-D. The main significant effect on taste and texture is variety, with both year and phase of the trial contributing additional significant effects. The overall effects of ethylene and carbon dioxide are minor and not significant (P>0.05).

Source	P value	Variance Explained
Variety	0.0000	81.8%
Ethylene	0.0765	1.2%
CO_2	0.6507	0.1%
Month	0.0213	2.0%
Year	0.1729	0.7%

TABLE 4.2A. INFLUENCE OF FACTORS FOR SAMPLE ON DIMENSION 1

Source	P value	Variance Explained
Variety	0.0002	21.0%
Ethylene	0.8246	0.0%
CO_2	0.7447	0.1%
Month	0.0000	36.9%
Year	0.3530	0.9%

TABLE 4.2B. INFLUENCE OF FACTORS FOR SAMPLE ON DIMENSION 2

Source	P value	Variance Explained
Variety	0.0874	2.6%
Ethylene	0.2230	0.8%
CO_2	0.7226	0.1%
Month	0.0000	13.2%
Year	0.0000	62.6%

TABLE 4.2C. INFLUENCE OF FACTORS FOR SAMPLE ON DIMENSION 3

Source	P value	Variance Explained
Variety	0.0089	14.1%
Ethylene	0.5965	0.4%
CO_2	0.5965	0.4%
Month	0.0076	10.5%
Year	0.0004	20.2%

TABLE 4.2D. INFLUENCE OF FACTORS FOR SAMPLE ON DIMENSION 4

Table 4.2 A-D Statistical breakdown of output from principal component analysis

5.4. Discussion

The results of the two years of trials clearly demonstrate that the significant factors for taste and texture determinants are potato variety, storage treatment period and, to a lesser extent, seasonal variation.

Taste and texture effects were more evident in the first phase of the trials, in both years of the study, for example increased waxiness and sweetening in Marfona and Estima (Table 4.1). This may be related to an effect of maturity, tubers in December being less mature and less stable in, for example, respiration rate than in May. It is well known that, for most cultivars, levels of reducing sugars increase during low temperature storage. These may directly affect flavour and, by contributing additional reactants to the Maillard reaction, also indirectly affect flavour of cooked tubers. Jansky (2010) reviewed the study of Thybo *et al* (2006) which concluded that the primary factors explaining variability in taste, colour and texture of (pre-peeled) boiled potatoes were cultivar and storage time over a period of 1, 1.5 and 6 months at 4^{o}C.

These results support other reports that components of potato flavour, a combination of factors including taste, aroma and texture, are influenced by genotype, and production and storage environments, reviewed by Jansky (2010). Seasonal variations in tuber composition can significantly impact on flavour, discussed in Jansky (2008). De Meulenar *et al* (2008) demonstrated that reducing sugars and free amino acid content both varied significantly over two years and speculated that these differences were due to the different climatic conditions experienced by the plants for those two years. A four year study by Hajslova *et al* (2005) demonstrated genotypic differences, seasonal differences, and locality variation for a range of tuber components, including glycoalkaloids and chlorogenic acid which may contribute to bitter or sour flavours. Agronomic decisions can affect tuber composition, harvest date and desiccant can having long lasting effects on post-harvest tuber physiology for example on respiration rates and changes in reducing sugars (Bethke and Busse 2010).

Overall no significant or consistent trends were identified by PCA or GLM on taste and texture attributes for ethylene or carbon dioxide treatments. Individual assessments detected an increase in sweetness by ethylene treatment and by carbon dioxide in Estima and Marfona. Sweet aftertaste was increased in the two varieties by ethylene. Marfona appearance and hardness of first cut was increased by ethylene. Other statistically significant effects, although noted, were not consistent, between storage duration phase or year to year. With the large number of assessments carried out, small and non-notable differences might be expected to be found statistically significant. However, statistical significance does not necessarily indicate practical significance. In neither year was there a strong association with ethylene or carbon dioxide, separately or together with any significant deleterious taste or texture attributes.

The results obtained with carbon dioxide alone support the statement by managers of store B in the store surveillance component of this project. This was that there were no apparent effects of high level of carbon dioxide exposure to the crops removed from the store with most having been used to supply supermarket contracts for high quality pre-pack potatoes. Deterioration in fry colour from ethylene exposure is reported to be exacerbated in the presence of carbon dioxide (Daniels-Lake *et al.*, 2005). However, the authors results showed no significant effect of carbon dioxide alone (at concentrations of 2%) on fry colour. The question "what level of CO2 is critical for potato quality?" in the management of processing potato stores is still to be answered convincingly.

Briddon (2006) in a review of the use of ethylene for sprout control, reported on taste and texture changes during 2004, specifically an increase in waxiness in King Edward and Maris Piper and the development of a "nutty" flavour in Marfona. In this study changes were noted, for example during 2008-09 first phase storage, including waxiness, sweetness, blackening-greying and breakdown rate increased in Marfona and Estima but not Maris Piper. Changes in hardness on first cut and first bite were also noted. The inability to replicate specific effects found during 2004, other than an increase in waxiness in Marfona but not Maris Piper, must be attributed to other factors or their combinations. It is possible that there are interactions between ethylene and/or carbon dioxide and taste and texture under particular conditions of potato production and storage that have not been experienced in the two years of the trial. It is also possible that the small number of individuals who made up the taste panel used in this study may not reflect the range of ability to detect differences in taste or texture that occur in the wider population.

The management of ethylene control of sprout suppression has evolved over the past decade or so to minimise any potential deleterious changes in potato quality. It is standard practise to gradually introduce ethylene to its final concentration over the course of a few weeks to minimise the respiration burst and consequent changes in, for example, the reducing sugar concentrations. There are differences between the two major suppliers of ethylene control systems in the timing of ethylene application either at store loading or at onset of sprouting. In the trials described above, no ramp was applied, ethylene was added to its immediate target of 10ppm, at two different time periods of storage, although not immediately at store loading. It might be expected that these conditions were optimal to observe deleterious changes in taste or texture attributes.

Tuber respiration rate generally declines rapidly over the first 1-2 weeks following harvest decreasing more slowly over the subsequent weeks. Tubers harvested early i.e. relatively immature, from desiccant-treated plants have higher respiration rates than those harvested from green vines, an effect that lasts for at least 12 weeks (Bethke and Busse 2010). Some effects might be expected with stressed and highly respiring plants, for example those at high temperature in conditions of inadequate air circulation. Ethylene, a potent stimulator of respiration, applied to warm, immature tubers in an air-tight store in which carbon dioxide had built up, might provide such a condition. In these trials, tubers were cold and, having been stored in good conditions since harvest, likely to have a stable, low, respiratory rate. This would have reduced the overall level of respiration that ethylene could potentially induce.

Ethylene is known to alter carbohydrate metabolism in stored potato tubers (Daniels-Lake *et al*. 2007) and the effects on Marfona and possibly Estima in relation to slightly increased sweetening are not unexpected, rather it might be expected to be seen more consistently and with other varieties. More extensive effects might be expected with longer periods of exposure to ethylene. Similarly it is possible that interactions between carbon dioxide and ethylene on taste and texture attributes were not detected because of the relatively short period of exposure to both gases.

Various stresses, singly or in combination, may cause exceptional levels of oxidative stress and consequent damage to cellular components and changes to plant physiology. Reactive oxygen species (ROS), a class of molecules including free radicals and peroxides, are generated unavoidably and inherently in all aerobic organisms as a consequence of aerobic metabolism. However, an imbalance between ROS production and antioxidant defences can lead to an oxidative stress and significant damage to cellular components, including cellular necrosis. Generation of ROS may be a consequence of environmental stress or, for example high levels of sugars, reviewed by Rhoads and Subbaiah (2007). Ethylene increases respiration (Reid and Pratt 1972) and therefore ROS production. Ethylene is known to induce cyanide-resistant respiration (Rychter et al 1978), a mechanism thought to reduce the level of oxidative stress (Maxwell et al. 1999) and indicates the complex biological role played by ethylene in plants. It is possible that oxidative stress is involved in blackheart, a physiological or condition thought to occur when tubers undergo periods of oxygen deprivation.

Stresses may occur during the growing season and be manifest in harvested potatoes. For example, the production of "musty" potatoes was associated with unusually hot (>30 °C) soil temperatures (Daniels−Lake et al, 2007).

These experiments have not supported the suggestion that short term (~5 week) exposures to ethylene and/or carbon dioxide are responsible for significant deleterious taste or texture attributes. The issues that were a possible cause for concern have to some extent abated as evidenced by the increased use of ethylene as sprout suppressant.

Cultivars Maris Piper and Marfona have been previously identified as being sensitive to ethylene and carbon dioxide use. Estima was included in the trial as the cultivar was considered relatively resistant to flavour modification. Although only Marfona was affected by ethylene use in both years for both storage phases, results in the first year suggest that Estima is also responsive to ethylene use.

5.5. Conclusions

Organoleptic characteristics of the cvs Estima, Marfona and Maris Piper were assessed by a trained taste panel after exposure to varying concentrations of carbon dioxide, with and without the addition of ethylene. The major determinants of flavour were variety and storage period and, to a lesser extent, season.

Ethylene and carbon dioxide concentrations were relatively insignificant. Changes in taste and texture were small and inconsistent between year and storage phase of the trial except a slight increase in sweetness in the variety Marfona. There was no finding of a deleterious effect produced by either gas. The assessment was conducted by a highly trained taste panel and even the small changes they recorded may not constitute changes that could be detected by consumers. However, under interactions of year, production and storage environments not replicated in this trial it is possible that ethylene with or without carbon dioxide may more significantly modify potato taste and texture.

Precautionary advice is to minimise the carbon dioxide in commercial store and .that users of ethylene should ensure they adhere closely to management advice given by their suppliers.

6. POTATO TUBER INFECTION BY BACTERIAL AND FUNGAL PATHOGENS AT DIFFERENT CARBON DIOXIDE INCUBATION ATMOSPHERES.

6.1. Introduction

It is well known that some serious infections of stored potato are aggravated by environmental conditions, especially temperature and humidity. *Pectobacterium carotovorum* and related species can be increased by altering the carbon dioxide and oxygen composition of the experiment (Powelson & Franc 2001, Perombelon & Van Der Wolf 2002). The experiments described in this section were carried out to determine whether the levels of carbon dioxide found in potato stores increased disease risk from *Pectobacterium* sp. and also of two fungal pathogens *Phoma exigua* and *Fusarium sulphureum,* the causes of gangrene and dry rot respectively. The range of carbon dioxide levels used in the following experiments were chosen to replicate a high value found in potato stores (3%) and also a much higher value (10%) to provide an extreme case to provide an experimental scale.

6.2. Material and methods

6.2.1. Pathogen preparation and inoculation

Pectobacterium carotovorum was isolated from an infected tuber, variety Marfona, showing characteristic symptoms of bacterial soft rot. Isolated and in culture, it caused pitting in CVP agar at 27 °C (Perombelon & Van Der Wolf 2002) and was characterised by both PCR and real time PCR as *P. carotovorum*. *Fusarium sulphureum* was isolated from naturally infected tubers. Displaying characteristic morphology in culture its identity was confirmed by real time PCR. A *Phoma exigua var foveata* culture was generously provided by Dr. Jane Thomas (NIAB). All pathogens were propagated via inoculated potato tubers to ensure they were capable of infecting tubers before use in the following experiments. *P. carotovorum* was grown on CVP agar at 27 °C and maintained at 4°C. *P. exigua* and *F. sulphureum* were grown at 17°C on ¼ strength Potato Dextrose Agar (PDA) and maintained at 4°C.

To prepare the bacterial pathogen inoculum *P. carotovorum* was grown in nutrient broth at 27°C to an OD_{600nm} of 2.0, determined to be ~ 10^8 cfu/ml and diluted to the final desired concentration of 10^6 cfu/ml in ambient temperature sterile water. To prepare the fungal pathogen inoculum, one half of a full grown Petri dish culture was macerated to homogeneity in water with a blender. For *F. sulphureum*, 9.1 g culture was macerated with 18.2 g sterile distilled water for 30 seconds. For *P. exigua*, 4.3 g culture was macerated with 17.2 g sterile distilled water for 76 seconds. For control mock inoculation, 9.2 g sterile PDA was macerated with 18.4 g sterile distilled water for 30 seconds.

6.2.2. Potato tubers

Estima tubers were equilibrated overnight to ambient temperature, washed for 2 min and left submerged in clean ambient temp water overnight to expand lenticels.

6.2.3. Inoculation and infection

Three experimental inoculation methods were used for *P. carotovorum* infection. Infection by infiltration (I or Inf) to mimic lenticellular infection. Approx 20 tubers were submerged in 4L of 10^6 cfu/ml *P. carotovorum* suspension in a plastic bucket fitting within the vacuum chamber. A vacuum was applied, maintained at minus 10 inch Hg for 5 min before the vacuum was released as quickly as possible. Tubers were removed from the bacterial suspension into a sink full of clean tap water, and submerged for 5 min to passively remove bacteria. They were not deliberately dried prior to incubation.
Infection can be initiated by pathogen entry via wounds and wounds were made to mimic different wound types caused during harvest and subsequent handling. Two wounds (W) were made on the same side of each potato. A 2.0 cm deep hole was made with a 4” nail and the hole immediately inoculated with 75ul of 10^8 cfu/ml *P. carotovorum*. The second wound was made with a 4” bolt. The bolt head was dipped in ~10^8 cfu/ml *P. carotovorum* suspension and immediately and forcibly pressed into the tuber surface, sufficiently to break the skin and leave a clear imprint of the side of the bolt head. After wounding both wound surfaces were wiped with tissue but otherwise the tubers were not soaked or rinsed prior to incubation.
Infection by wounding and infiltration (WV); other types wounds were made by pressing one side of the tuber, and on the other side by pressing and twisting, into the bed of drawing pins fixed into a computer mouse mat. Each tuber was immediately placed into a *P. carotovorum* suspension at 10^6 cfu/ml, and vacuum infiltrated at - (minus) 20 inch Hg for 10 min. Following rapid vacuum release the tubers were submerged in a sink full of clean tap water for 5 min. They were not deliberately dried prior to incubation.

For *P. exigua* and *F. sulphureum* inoculations tubers were wounded using the “clip” part of the top of a Bic ballpoint pen. This was pushed into the tuber to a set mark and a circular movement producing a narrow deep hole of reproducible size 21 x 4 mm. Inoculations were carried out by placing 220 microlitres of control or pathogen macerate into the puncture hole.
Control (C) tubers were treated as for pathogen inoculations but with water only. Tubers were randomly allocated from each batch of inoculations into each of the carbon dioxide conditions.

Thirty tubers were inoculated with each pathogen and 10 control tubers were mock inoculated for each carbon dioxide atmosphere.

6.2.4. Incubation conditions

Tubers were incubated at ambient %, 3% or 10% carbon dioxide at 12°C for 28 days in 0.56 m^3 CA chambers (CA 1, 2 and 3 respectively) within 6-tonne stores at 20°C. Carbon dioxide was controlled within 10% of the set point and oxygen monitored. Ambient carbon dioxide was maintained essentially by continuous air flushing of the chamber. The concentration of the gases over the course of the incubation shown in the appendix 3.1a-c and similar results were obtained for all trials. Humidity was maintained by flooding the base of the chamber with water.

To confirm infection was possible, tubers were also held in 9L respiration boxes flushed with N_2 to bring the oxygen atmosphere below 1%. These initial atmospheres in the chambers were not deliberately maintained but carbon dioxide and oxygen concentrations were measured at the end of experiment.

The duration of the experiments was decided by visual inspections during the experiment, and were 7 day for oxygen low/free atmosphere incubation and at least 30 days for carbon dioxide controlled atmosphere experiments.

Following incubation tubers were stored at 3.5 °C until analysis. This was within 1 day for both the zero time and oxygen low/free samples. Carbon dioxide controlled atmosphere experiments were processed in order of decreasing visual symptoms and within 10 days.

6.2.5. Sample preparation and analysis

Tuber peel samples were prepared as described in annex 3.2. Qiagen DNeasy Plant Mini kit was used to isolate DNA from peel samples using the kit protocol. A semi-quantitative visual assessment of symptoms of infection for each tuber was scored as follows: No rot = 0 point, slight rot = 2 point obvious rot = 5 points and extensive rot =10 points.

6.2.6. Quantitative analysis of pathogen DNA

Quantitative analysis of *P. carotovorum* numbers was carried out by real time PCR, as described in Appendix 1 section 3. A standard curve of *P. carotovorum* infection was prepared as in annex 3.4. *P. exigua* and *F. sulphureum* DNA were quantitatively analysed using real time PCR using the methods of Cullen *et al.* (2005) and Cullen *et al.* (2007) respectively.

6.3. Results

Components of the experimental system were developed in preliminary experiments (not shown). During these experiments tubers failed to develop infection. Likely reasons were identified as experimental conditions, particularly of temperature and of inoculation, were not optimal or sufficient for *P. carotovorum* infection. For this reason the more conducive conditions for *P. carotovorum* infection of a higher incubation temperature (20 rather than 10°C) were used. Tubers were also stressed by overnight water submersion prior to inoculation and the more thorough wounding condition described in the materials and methods were also employed.

Highly stressed tubers, such as under semi-anaerobic incubation conditions, are very vulnerable to infection and were used to rapidly confirm that the pathogens were capable of infecting potato tubers. Infection was monitored visually and by PCR. The results of the semi-anaerobic incubation, shown in appendix 1 section 5 and 6, confirm that all three pathogens were capable of infecting potato tubers. Visual analysis of the symptoms in inoculated tubers in the main experiment also showed similar successful infection by the pathogens.

Box plots are shown to provide a visual comparative summary of the range and distribution of data across the individual experiments. The minimum (Min) and maximum (Max) data points, the 25th percentile (Q25), the median and the 75th percentile (Q75) are shown.

6.3.1. *P. carotovorum* infection of tubers under controlled carbon dioxide incubation conditions

6.3.1.1. Visual estimation of P. carotovorum infection

Each tuber was scored using a "semi-quantitative" scoring system; results are shown in Figure 5.1. This provided an early method of scoring infection and a guide as to the order for subsequent processing of the experimental tubers. *P. carotovorum* infection is found under all three carbon dioxide conditions, increased at higher carbon dioxide atmospheres. The most infection is seen for the most aggressively wounded tubers (VW) and slightly less in wounded (W). Little to no infection is seen with infiltration inoculated tubers except at 10% CO_2.

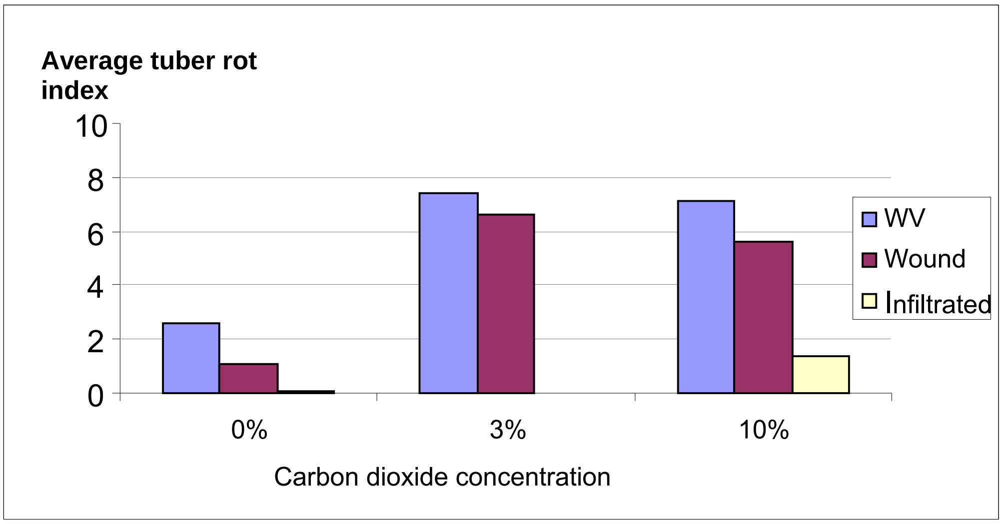


FIGURE 5.1. VISUAL ESTIMATE OF *P. CAROTOVORUM* INFECTION OF POTATO TUBERS UNDER CONTROLLED CARBON DIOXIDE INCUBATION CONDITIONS.

6.3.1.2. Quantification of P. carotovorum *infection*

The numbers of *P. carotovorum* were quantified in a sub-sample of tubers for each inoculation and carbon dioxide condition. This experiment was carried out two times and similar results were found both times. The results for one experiment are shown in Figure 5.2, the box plot in Figure 5.3 shows the distribution of sample results within each condition for this experiment. In both experiments *P. carotovorum* infection occurred under all three carbon dioxide conditions and there was always an increase in infection at higher carbon dioxide conditions compared to ambient carbon dioxide % atmosphere for all inoculation methods. Significant differences ($P < 0.05$) were observed between the infections at ambient and at other carbon dioxide concentrations.

Wound inoculated tubers contain more bacteria at all carbon dioxide conditions than other methods of inoculation. For one experiment more bacteria were found when tubers were incubated at 3% carbon dioxide whereas in the other experiment more bacteria were found at 10% incubation.

Inoculation by infiltration was successful at 10% carbon dioxide on both occasions but occurred at 3% carbon dioxide on the only one occasion. More bacteria were always found at 10% carbon dioxide than under other conditions.

The variation of bacterial numbers sample may be large because individual sample tubers within a treatment vary from uninfected to extensively infected and there is a very large difference in bacterial numbers in uninfected compared to extensively infected samples, Figure 5.3.

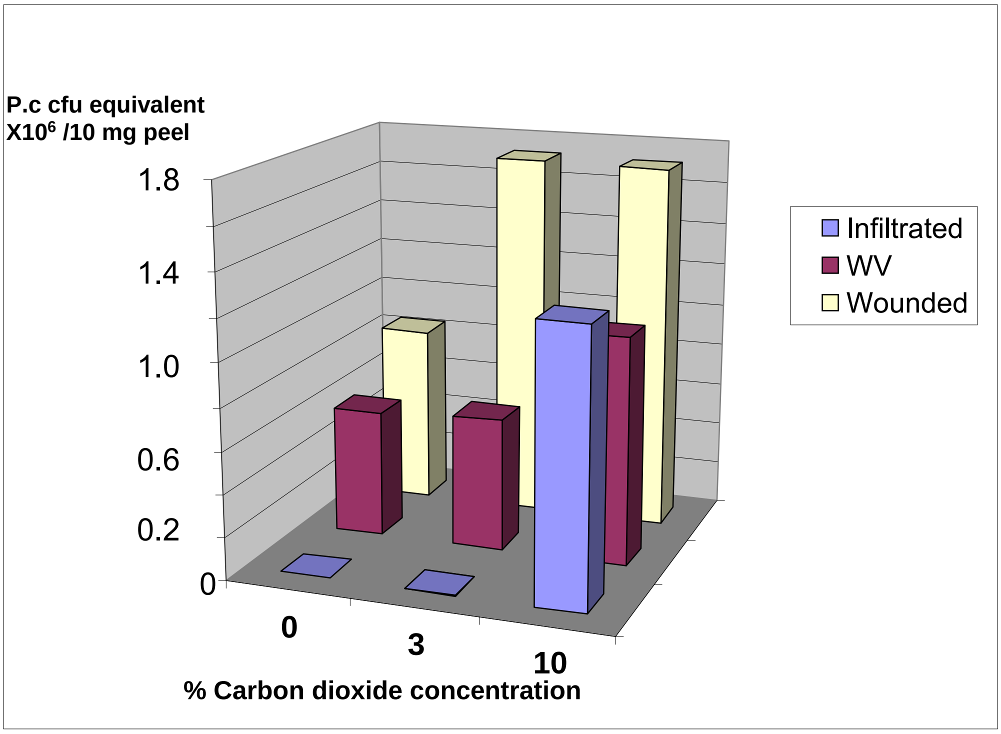


FIGURE 5.2. QUANTITATIVE ANALYSIS OF *P. CAROTOVORUM* INFECTION OF POTATO TUBERS BY THREE DIFFERENT INOCULATION METHODS UNDER CONTROLLED CARBON DIOXIDE ATMOSPHERE CONDITIONS

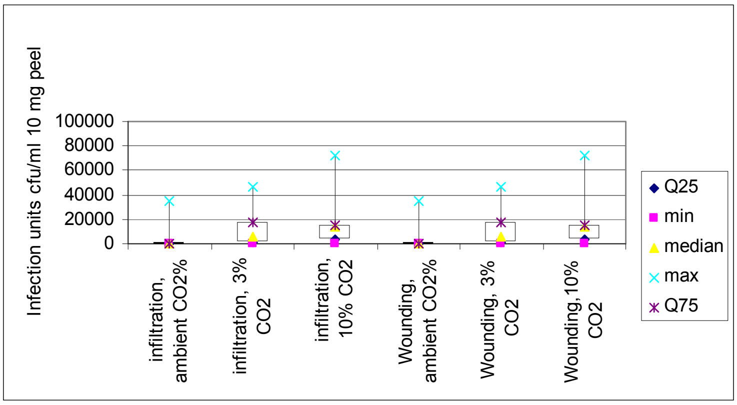


FIGURE 5.3. BOX PLOT ANALYSIS OF *P. CAROTOVORUM* INFECTION IN TUBERS INOCULATED BY INFILTRATION OR WOUNDING AT DIFFERENT CARBON DIOXIDE ATMOSPHERES

6.3.1.3. *P. exigua* ***infection of tubers under controlled carbon dioxide incubation conditions***

This experiment was carried once. One control (mock inoculated) tuber showed characteristic infection by *P. exigua* but it is unknown how this infection occurred. This tuber was included in subsequent analysis. No other control tuber showed evidence of infection nor was pathogen DNA detected. The box plot Figure 5.4 shows the range of infection values at each carbon dioxide condition. Although the overall levels of infection were not high, overall infection increases with increasing carbon dioxide as seen in Figure 5.5. The increased infection seen at the highest carbon dioxide atmosphere compared to the other treatments is significant ($P < 0.05$).

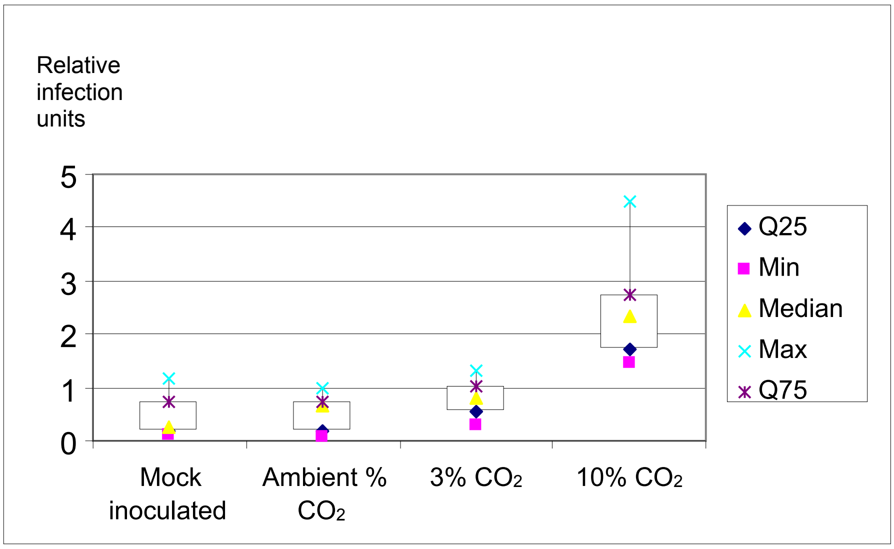


FIGURE 5.4 BOX PLOT ANALYSIS OF *P. EXIGUA* INFECTION OF POTATO TUBERS UNDER CONTROLLED CARBON DIOXIDE ATMOSPHERE CONDITIONS

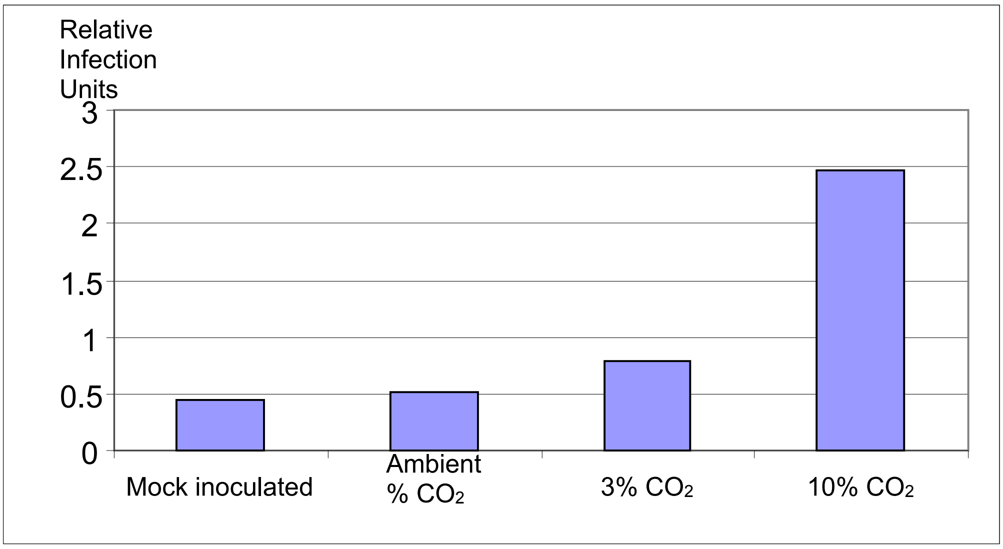


FIGURE 5.5 *P. EXIGUA* INFECTION OF POTATO TUBERS UNDER CONTROLLED CARBON DIOXIDE ATMOSPHERE CONDITIONS

6.3.1.4. F. sulphureum *infection of tubers under controlled carbon dioxide incubation conditions*

This experiment was carried once. The results of *F. sulphureum* inoculation are shown in Figure 5.6 and 7. The box plot Figure 5.6 shows the range of infection values at each carbon dioxide condition. Infection decreases with increasing carbon dioxide (Figure 5.6) with significant differences ($P < 0.05$) between the infections at 10% compared to the other carbon dioxide concentrations.

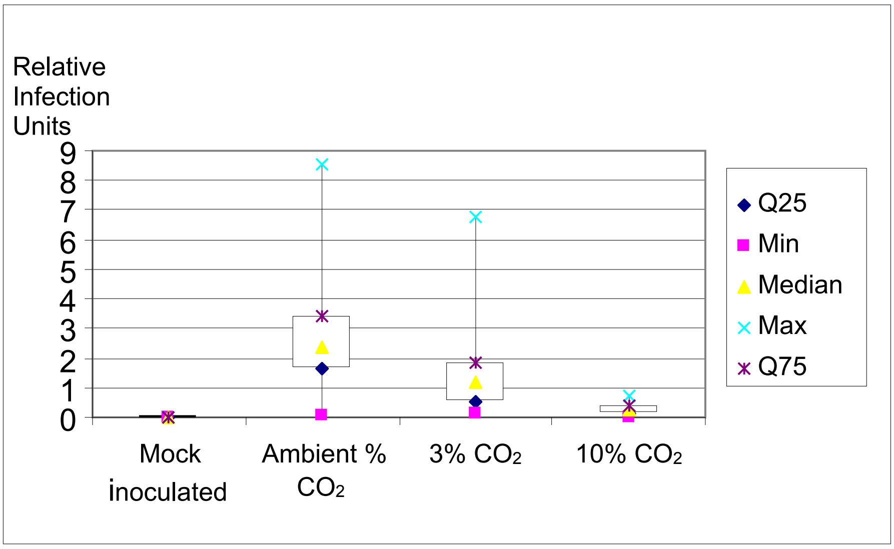


FIGURE 5.6. BOX PLOT ANALYSIS OF *F. SULPHUREUM* INFECTION OF POTATO TUBERS UNDER CONTROLLED CARBON DIOXIDE ATMOSPHERE CONDITIONS

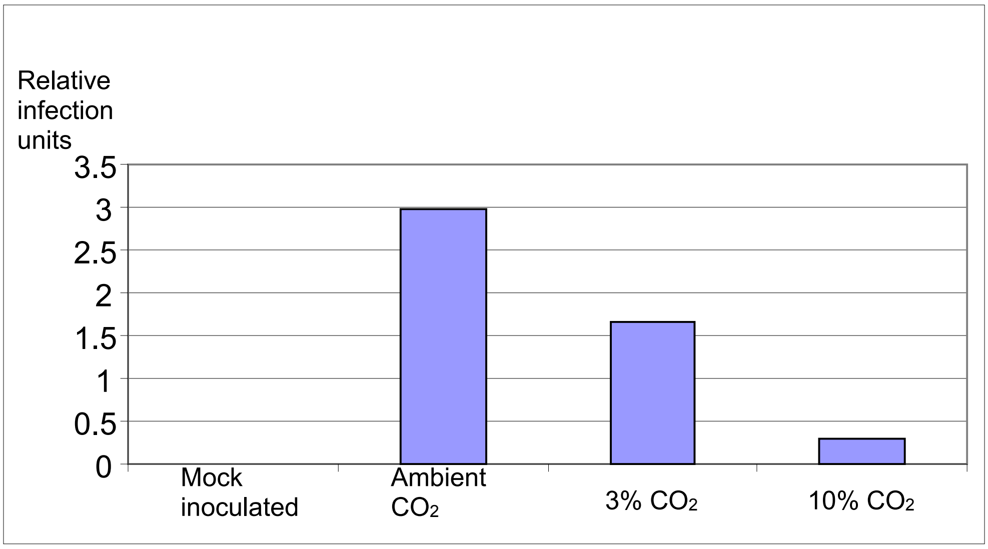


FIGURE 5.7. *F. SULPHUREUM* INFECTION OF POTATO TUBERS UNDER CONTROLLED CARBON DIOXIDE CONDITIONS

6.4. Discussion

6.4.1. Pathogen detection

Protocols for sample preparation and for real time PCR quantitative detection of three serious pathogens of potato have been successfully developed for use in Sutton Bridge trial work. These protocols are able to allow the rapid and reliable quantification of the pathogens used in these experiments over at least 4 orders of magnitude

6.4.2. Infection and incubation temperature

P. carotovorum isolated from an infected tuber at Sutton Bridge was able to infect and rot potato tubers at 20 °C within a month. However, with the same bacterial isolate and potato variety in an earlier very similar experiment no infection was observed at 10 °C over the course of one month. Tuber storage conditions are generally below 10 °C hence the conditions employed in the current experiment are not directly relevant to storage. Nevertheless they provide a framework in which we can assess the effect of varying the % carbon dioxide atmosphere on bacterial capacity to infect tubers over relatively short time scales.

The inoculation methods of wounding and vacuum infiltration have been used in other scientific studies as to mimic the typical routes of natural infection entry via wounds and lenticels retrospectively. Here, both methods were successful and showed they can be used to give a range of different infection rates, for example wounding caused a higher incidence of infection than vacuum infiltration.

6.4.3. Carbon dioxide concentration and pathogen infection

These preliminary results demonstrate that microorganisms can have different responses to altered carbon dioxide levels and that a change may be detrimental to one and beneficial to another. A confounding variable in our experimental system is that oxygen was not controlled during the incubation and varied depending on the carbon dioxide concentration (Appendix 5.1 a-c). Increased carbon dioxide may be a stress that leads to increased respiration and therefore increased oxygen consumption. The range of carbon dioxide incubation conditions used here includes a high value (3%) that has been found in potato stores and, for *Pectobacterium* infection this level was shown to significantly increase the rate of infection.

Previous studies have related an increase in *Pectobacterium* infection with very decreased oxygen concentrations and it is thought that oxygen depletion rather than carbon dioxide accumulation is the important factor (Lund and Nicholls, 1970). The above experiments differ in that the oxygen concentration is altered much less than in the example of Lund and Nicholls (1970) in which the oxygen concentrations was reduced to essentially zero. There is no literature expressly relating increasing *Pectobacterium* infection with % carbon dioxide concentration and these experiments provide a strong indication of an effect of carbon dioxide concentration on a *Pectobacterium* infection.

The results indicate that *F. sulphureum* infection decreases with increasing % carbon dioxide concentration whereas *P. exigua* infection increases with increasing % carbon dioxide concentration. The genus *Fusarium* has previously been extensively studied with regard to the effect of carbon dioxide concentration on activity or reproduction, and show wide variation in response at the species level. Stover & Freiberg (1958) demonstrated an increase multiplication of *Fusarium oxysporum* at higher carbon dioxide atmospheres. Walsh and Stewart (1971) noted the cellulolytic activity of fungi at varying oxygen concentrations (20–1%, v/v) and carbon dioxide concentrations (0–15%). In this study high carbon dioxide concentration stimulated *F. solani* and *F. moniliforme* whereas it caused marked inhibition of *F. culmorum*. This last case mirrors the results found here with *F. sulphureum.* The genus *Phoma* have not been as extensively investigated but gangrene, caused by *P. exigua*, has been shown responsive to altered atmospheric conditions, principally of oxygen (Khanbari and Thompson 1996).

Given the potential effect of altered carbon dioxide to affect the relationship between pathogen and tuber, it must be judged prudent to minimise carbon dioxide build-up in store. Ethylene was not included in these experiments and hence no information is provided about possible effects on infection of tubers.

6.5. Summary conclusions

- An effective experimental system has been set up that allows the relationship of microbial infection of potato tubers to environmental carbon dioxide concentrations to be investigated
- Pathogen numbers can be accurately quantified at SBCSR using real time PCR
- *Pectobacterium carotovorum* infection increases with increasing % carbon dioxide concentration
- *Fusarium sulphureum* infection decreases with increasing % carbon dioxide concentration
- *Phoma exigua* infection increases with increasing % carbon dioxide concentration
- 3% carbon dioxide has an effect on pathogen infection rates
- Store levels of carbon dioxide should be controlled, not least to minimise the increased possibilities of fungal and bacterial rot disease.

7. FURTHER WORK:

The current experiments have not revealed any damaging consequences for crops held with even very high (>4%) levels of carbon dioxide in the store atmosphere. There is no straightforward resolution to the question "What level of carbon dioxide is critical for potato quality?"

There is still a lack of clarity on the effect of carbon dioxide on respiration in tubers, an area that has significance in the use of alternative sprout suppressants.

Whilst carbon dioxide level may have a bearing on taste and texture effects, not identified in the current study, it may be that the levels are very significant in relation to the development of physiological conditions influencing tuber quality, such as blackheart, in specific crops. These problems are, on the basis of information from the PCL Storage Discussion Group and coming into the Sutton Bridge Storage Advice Line, increasing in prevalence in storage but remain under-researched.

A meeting of the PCL Storage Discussion Group (Terry & Harper, 2010) considered many of these points but it was clear from discussion of these results and consideration of earlier, relevant research, that there are still significant areas where knowledge is lacking. Questions which remain to be answered include:

- How does carbon dioxide affect tuber respiration?
- What are the roles of other store atmosphere components, including oxygen, in affecting respiration?
- Does oxidative stress play a role in quality changes of stored potato tubers?
- Can confounding experimental variables of oxygen and carbon dioxide within the incubation environment be avoided or minimized during the measurement of physiological processes?
- Is there an interaction between ethylene and disease? For example *Fusarium* spp. Infection has been reported as stimulating ethylene production (Creech *et al.* 1973).

8. References

Anon. (1997)…But carbon dioxide can be damaging. Sutton Bridge Experimental Unit Annual Review 1996. PMB, Oxford. pp 9-10.

Anon. (2001) BPC Handbook – Pests & Diseases. 4th edition. BPC/NIAB. 49pp.

Bethke, P. C. and Busse, J.S. (2010) Vine-kill treatment and harvest date have persistent effects on tuber physiology. *American Journal of Potato Research.* 87, 299-309

Briddon, A., 2006. Review of the use of ethylene for sprout control (R279). Potato Council

Briddon, A. & Jina, A. (1996). The effect of carbon dioxide on processing quality. Sutton Bridge Experimental Unit Annual Review 1995. PMB, Oxford. pp 33-36.

Burton W.G. (1952) Studies on the dormancy and sprouting of potatoes. *New Phytology* 50, 287-296.

Creech, D. L. Workman, M. and Harrison M. D. 1973. The influence of storage factors on endogenous ethylene production by potato tubers. *American Journal of Potato Research* 50, 145-150.

Cullen, D.W., Toth, I.K., Pitkin, Y., Boonham, N., Walsh, K., Barker, I. and Lees, A.K. 2005. Use of Quantitative Molecular Diagnostic Assays to Investigate Fusarium Dry Rot in Potato Stocks and Soil. *Phytopathology* 95, 1462-1471.

Cullen, D.W., Toth, I.K., Boonham, N., Walsh, K., Barker, I. and Lees, A.K. 2007. Development and validation of conventional and quantitative Polymerase Chain Reaction assays for the detection of storage rot potato pathogens, Phytophthora erythroseptica, Pythium ultimum and Phoma exigua. *Journal of Phytopathology* 155, 309-315.

Daniels-Lake, B.J., Prange, R.K., Kalt, W. and Walsh, J.R. (2007a). Methods to minimize the effect of ethylene sprout inhibitor on potato fry colour. *Potato Research* 49, 303-326.

Daniels−Lake, B.J., Prange, R.K., Gaul, S.O., McRae, K.B., de Antueno, R., and McLachlan, D. (2007b). "A Musty "Off" Flavor in Nova Scotia Potatoes Is Associated with 2,4,6−Trichloroanisole Released from Pesticide−treated Soils and High Soil Temperature.", Journal of the American Society for Horticultural Science, 132, pp. 112−119.

De Meulenaer, B., Tineke De Wilde, T., Mestdagh, F., Govaert, Y., Ooghe,W., Fraselle, S., Demeulemeester, K., Van Peteghem, C.V., Calus, A., Degroodt, J-M. and Verhe, R. (2008). Comparison of potato varieties between seasons and their potential for acrylamide formation. *Journal of the Science of Food and Agriculture* 88, 313-318

Hajslova ,J., Schulzova, V., Slanina, P., Janne, K., Hellena, K. E. and Andersson, C.H. (2005).Quality of organically and conventionally grown potatoes: Four-year study of micronutrients, metals, secondary metabolites, enzymic browning and organoleptic properties. *Food Additives and Contaminants.* 22, 514–534

HSE (2007) Control of Substances Hazardous to Health – COSHH: List of approved workplace exposure limits (EH40/2005 as consolidated with amendments October 2007). Health & Safety Executive. www.hse.gov.uk/coshh.

Jansky S.H. (2010). Potato Flavor. *American Journal of Potato Research.* 87, 209-217

Jansky, S. (2008). Genotypic and environmental contributions to baked potato flavor. *American Journal of Potato Research.* 85, 455-465.

Khanbari, O. S. and Thompson, A. K. 1996. Effect of controlled atmosphere, temperature and cultivar on sprouting and processing quality of stored potatoes. *Potato Research* 39, 523-531.

Lund, B. M. and Nicholls, J. C. 1970. Factors influencing the soft-rotting of potato tubers by bacteria. *Potato Research* 13, 210-214.

Mapson L.W. and Burton W.G. (1962). The terminal oxidases of the potato tuber. *Biochemical Journal*, 82, 19-25.

Maxwell D.P., Wang Y, McIntosh L (1999). "The alternative oxidase lowers mitochondrial reactive oxygen production in plant cells". Proc. Natl. Acad. Sci. U.S.A. 96 (14): 8271–6.

Perez-Trejo M. S., Janes H. W. and Frenkel C. (1981) Mobilization of Respiratory Metabolism in Potato Tubers by Carbon Dioxide Plant Physiology 67:514-517.

Pérombelon, M.C.M. (2002) Potato diseases caused by soft rot erwinias. Plant Pathology 51, 1-12.

Perombelon. M & J. M. Van Der Wolf 2002. The Erwinia Manual. Scottish Crop Research Institute *Revised Version.*

Powelson, M.L. & Franc, G.D. (2001). Blackleg, aerial stem rot and tuber soft rot. In. WR Stevenson, R Loria, G Franc & DP Weingartner, eds. Compendium of Potato Diseases. The American Phytopathological Society, Minnesota. Pp. 10-11.

Reid M. S. and Pratt H. K. (1972) Effects of Ethylene on Potato Tuber Respiration. Plant Physiology 49, pp 252–255.

Rhoads D.M. and Subbaiah C.C. (2007) Mitochondrial retrograde regulation in plants. Mitochondrion 7: 177–194.

Rychter A, Janes, H. W. and Frenkel C. 1978 Cyanide-resistant Respiration in Freshly Cut Potato Slices. Plant Physiology April; 61(4): 667–668.

Rylski, I., L. Rappaport and H.K. Pratt, 1974. Dual effects of ethylene on potato dormancy and sprout growth. *Plant Physiology*. 33: 638-662.

Small. D. and. Pahl, K. (2005.). http://www.gov.mb.ca/agriculture/crops/potatoes/bda04s06.html

Stover R. H. and Freiberg S. R. 1958. Effect of Carbon Dioxide on Multiplication of Fusarium oxysporum in soil. *Nature* 181, 788-789.

Suslow, T. V. and Voss, R. (2009) http://postharvest.ucdavis.edu/Produce/ProduceFacts/Veg/potato-early.shtml

Terry, L.A. and Harper G. (2010) Tuber respiration and blackheart. Presentation to the Potato Council Storage Discussion Group, Sutton Bridge Crop Storage Research, 25 November 2010. *Unpublished*.

Thybo, A.K., Kaack, C. K. and Peterson, M.A. (2006). Effect of cultivars, wound healing, and storage on sensory quality and chemical components in pre-peeled potatoes. *LWT-Food Science and Technology* 39, 166-176. (cited but not read)

Walsh J.H. and Stewart C.S. 1971. Effect of temperature, oxygen and carbon dioxide on cellulolytic activity of some fungi. *Transactions of the British Mycological Society* 57, 75-84.

9. ANNEX 1: LFI 2007-08 REPORT ON STORE CARBON DIOXIDE AND ETHYLENE LEVEL EFFECTS ON POTATO FLAVOUR AND TEXTURE CHARACTERISTICS TASTE AND TEXTURE ASSESSMENT

9.1.1. Samples

The first batch of potatoes, assessment 1 (Jan 2008) were supplied by Sutton Bridge and were delivered on the 7th January 2008, and evaluated between 8-15th January 2008. The second batch of potatoes, assessment 2 (June 2008) were delivered on the 16th June 2008 and evaluated between the 17-24th June 2008. For details of the potato varieties supplied see Table A1.

Sample Code		Sample Details		
Assessment 1	**Assessment 2**	**Variety**	**Untreated/Ethylene**	**Atm CO_2**
6100/01	**6160/61**	Estima	Untreated	0.5
6102/03	**6162/63**	Estima	Untreated	1.5
6104/05	**6164/65**	Estima	Untreated	3
6106/07	**6166/67**	Estima	Untreated	4.5
6108/09	**6168/69**	Estima	Untreated	6
6116/17	**6170/71**	Estima	Ethylene	0.5
6112/13	**6172/73**	Estima	Ethylene	1.5
6114/15	**6174/75**	Estima	Ethylene	3
6110/11	**6176/77**	Estima	Ethylene	4.5
6118/19	**6178/79**	Estima	Ethylene	6
6120/21	**6180/81**	Marfona	Untreated	0.5
6122/23	**6182/83**	Marfona	Untreated	1.5
6124/25	**6184/85**	Marfona	Untreated	3
6126/27	**6186/87**	Marfona	Untreated	4.5
6128/29	**6188/89**	Marfona	Untreated	6
6136/37	**6190/91**	Marfona	Ethylene	0.5
6132/33	**6192/93**	Marfona	Ethylene	1.5
6134/35	**6194/95**	Marfona	Ethylene	3
6130/31	**6190/91**	Marfona	Ethylene	4.5
6138/39	**6198/99**	Marfona	Ethylene	6
6140/41	**6200/01**	Maris Piper	Untreated	0.5
6142/43	**6202/03**	Maris Piper	Untreated	1.5
6144/45	**6204/05**	Maris Piper	Untreated	3
6146/47	**6206/07**	Maris Piper	Untreated	4.5
6148/49	**6208/09**	Maris Piper	Untreated	6
6156/57	**6210/11**	Maris Piper	Ethylene	0.5
6152/53	**6212/13**	Maris Piper	Ethylene	1.5
6154/55	**6214/15**	Maris Piper	Ethylene	3
6150/51	**6216/17**	Maris Piper	Ethylene	4.5
6158/59	**6218/19**	Maris Piper	Ethylene	6

Changes to the sample code are shaded in grey

TABLE A1. POTATO SAMPLES ASSESSED – ASSESSMENT 1 AND 2

9.1.2. Sensory Panel

11 assessors drawn from the trained sensory panel at LFI took part in Assessment 1 and 10 assessors took part in Assessment 2. All assessors are trained in the sensory evaluation of an extensive range of food and beverage products including potatoes and were familiarised with the Potato Council potato references prior to experimental assessments, as described below.

9.1.3. Product Profiling

A sensory profile was developed based on the principles of quantitative descriptive analysis (QDA).

9.1.4. Vocabulary generation and training

Assessors independently evaluated each of the samples and provided a detailed sensory description of the product. The panel then discussed their views and generated a consensus vocabulary, which consisted of specific attributes and definitions. The final glossary against which the 30 products were scored is detailed in Table A2. References were identified to clarify particular sensory attributes and these are shown in Table A3.

Attribute	Definition	Scale
Aroma		
Overall aroma intensity	Total aroma strength	Weak-Strong
Potato	Boiled potato aroma	Not-Very
Fishy	Aroma of mackerel / salmon	Not-Very
Earthy	Musty / earthy aroma	Not-Very
Cabbage water	Aroma of cooked cabbage / water	Not-Very
Off	A typical aroma	Not-Very
Appearance		
Colour	Intensity of colour	Light-Dark
Smooth	Smoothness of outer potato surface	Not- Very
Dry	Dryness of samples surface	Not- Very
Blemishes	Presence of visual defects	None-Many
Glassiness	Glassy appearance.	Not- Very
Blackening/greying	Grey / blackening of potato surface after cooking	Not- Very
Mottled	Unevenness of surface colour	Not- Very
Surface Disintegrating	Collapsing surface	Not- Very
Hardness on 1st cut (cut potato into 2)	Hardness on sample when cutting	Not-Very
Mouthfeel/Texture		
Hardness on 1st bite	Hardness of sample when sheared, by front teeth	Not-Very
Crumbly	When shearing, the collapsibility of sample in mouth	Not-Very
Absorbent	Cotton wool effect / takes all moisture from mouth	Not-Very
Waxy	Wax crayon, smooth shear	Not-Very
Gluey	Stickiness of potato	Not-Very
Floury	Dry powderiness of sample	Not-Very
Cloying	Bits stuck between teeth and on the palate	Not-Very
Grainy	Texture reminiscent of undercooked semolina	Not-Very
Breakdown rate	Speed of breakdown	Slow-Fast
Flavour		
Overall flavour intensity	Total flavour strength	Weak-Strong
Potato	Boiled potato flavour	Not-Very
Sweet	Sweetness of potato	Not-Very
Fishy	Flavour of mackerel / salmon	Not-Very
Earthy	Musty / earthy	Not-Very
Sour	Sourness of sample (lactic)	Not-Very
Bitter	Bitterness of sample	Not-Very
Metallic	Flavour of ferrous sulphate / blood	Not-Very
Soapy	Flavour of soap	Not-Very
Cabbage water	Flavour of cooked cabbage / water	Not-Very
Off	Atypical flavour	Not-Very
Aftertaste		
Overall aftertaste	Total aftertaste strength	Weak-Strong
Potato	Boiled potato aftertaste	Not-Very
Metallic	Aftertaste of ferrous sulphate / blood	Not-Very
Earthiness	Musty / earthy aftertaste	Not-Very
Sourness	Sourness of sample (lactic)	Not-Very
Bitter	Bitterness of sample	Not-Very
Afterfeel		
Cloying	Bits stuck between teeth and on the palate	Not-Very
Astringent	Drying effect in mouth	Not-Very
Mouthcoating	Coating in mouth after swallowing	Not-Very
Irritant	Abrasive feel	Not-Very

TABLE A2: POTATO COUNCIL GLOSSARY OF TERMS

Attribute	Reference
Fishy	**Princes Mackerel fillets in lightly salted water**
Earthy	**Baby new potato skins, Maris Peer/Exquista**
Savoury	**Spam**
Cabbage water	**The water cabbage has been boiled in**
Floury	**Tesco canned chick peas**
Astringent	**Tesco canned chick peas/ Maris Peer new potato skin**
Waxy	**Exquista new potato**
Gluey	**Sainsburys basics pasta boiled and left in water**
Sour	**Baby new potato skins, Maris Peer**
Metallic	**Baby new potato skins, Maris Peer**

TABLE A3. REFERENCES USED FOR POTATO ATTRIBUTES

A member of the Potato Council attended the first day of assessment 2 and viewed the preparation process and the assessments being made.

9.1.5. Design

All potato samples were tested in triplicate, whereby all assessors evaluated the thirty potatoes three times - at each timepoint. For practical and consistent presentation of the potatoes, each replicate was divided in ten sessions, each compromising of three different potato samples, presented in a random order. Over the three replicates each potato variant was seen with six other samples. Replicates were presented over three days.

9.1.6. Assessment

Each assessor carried out individual evaluations of all the test samples. All 30 test samples were presented in a sequential monadic randomised fashion.

- All samples were presented to the assessors directly from the steamers
- All samples were tested in triplicate
- All assessments were carried out in separate booths at them LFI sensory facility
- Assessors used line scales to indicate intensity of attributes
- Sensory data was collected using a computerised acquisition system, Compusense 5 v4.8

9.1.7. Data Analysis

The data from each panellist was pooled and analysed to determine the differences between the samples. Data was analysed using Senpaq version 3.9 and Microsoft® Excel 2002, SP3.

9.1.8. Results

This section presents the results acquired for the Potato Council potato samples in mean score tables, statistically significantly different attributes are shown graphically and trends are discussed.

	Estima										Marfona										Maris Piper										
	Untreated					Treated					Untreated					Treated					Untreated					Treated					
	6100/01	6102/03	6104/05	6106/07	6108/09	6116/17	6112/13	6114/15	6110/11	6118/19	6120/21	6122/23	6124/25	6126/27	6128/29	6136/37	6132/33	6134/35	6130/31	6138/39	6140/41	6142/43	6144/45	6146/47	6148/49	6156/57	6152/53	6154/55	6150/51	6158/59	LSD
Aroma																															
Overall aroma intensity	37.5	40.3	35.9	32.6	34.7	34.3	32.6	34.8	37.7	33.8	29.0	30.8	37.2	28.4	32.7	35.6	32.5	38.1	32.9	32.6	29.8	33.3	34.0	32.3	32.5	36.6	40.2	36.3	33.9	35.0	NS
Potato	29.7	33.1	27.8	25.8	27.4	25.5	24.8	24.1	26.5	25.3	21.5	23.0	23.0	21.0	22.1	24.1	22.4	24.1	25.5	25.1	24.9	21.9	25.9	26.6	26.7	26.7	28.0	28.5	24.8	25.4	5.2
Fishy	7.2	5.9	9.1	3.5	3.7	7.5	9.8	10.5	10.5	7.7	5.9	5.4	7.9	7.5	12.7	5.2	6.1	9.8	9.5	8.6	3.8	5.0	4.6	2.6	5.1	11.0	8.1	5.7	4.6	7.3	5.5
Savoury	0.2	0.7	1.3	1.3	0.1	0.8	0.8	1.4	2.2	1.9	1.3	1.6	1.6	0.1	1.8	0.8	1.1	0.0	1.4	0.2	1.2	1.6	4.3	1.9	1.1	1.4	2.1	1.3	2.9	4.1	NS
Earthy	20.5	24.7	17.8	19.3	23.1	18.2	16.4	16.5	19.6	18.4	11.8	16.0	11.2	13.0	10.8	18.2	17.4	17.7	12.7	15.2	16.4	15.1	16.7	17.5	15.6	17.5	16.6	14.6	18.2	14.5	6.4
Cabbage water	20.1	23.7	21.9	23.7	19.8	21.5	23.9	20.6	19.4	21.5	19.5	23.4	24.5	20.8	18.7	25.4	24.4	24.0	19.4	23.3	18.1	19.6	19.8	16.0	16.4	22.6	25.3	18.8	17.8	20.9	NS
Off	1.5	0.1	1.1	2.1	1.9	1.3	0.7	2.5	4.9	1.5	1.0	2.6	6.7	0.6	2.2	5.1	2.6	2.4	4.0	0.5	4.2	4.6	1.8	4.6	2.3	5.5	1.0	3.2	3.1	1.4	NS
Appearance																															
Colour	38.6	45.3	47.7	49.5	48.4	50.2	51.3	62.0	57.7	53.6	55.1	60.5	64.6	65.4	62.7	68.4	69.8	66.5	69.5	62.9	24.9	30.7	38.7	35.9	29.3	45.7	49.2	44.5	36.4	43.6	7.9
Smooth	67.7	68.4	74.2	63.3	64.7	74.0	77.0	79.9	73.4	69.3	76.2	76.9	75.6	74.6	77.4	77.1	78.7	78.0	77.8	78.5	30.6	44.6	54.2	41.2	30.3	55.0	60.5	66.7	58.0	49.3	8.7
Dry	23.3	19.0	17.8	17.4	22.0	20.5	19.7	19.6	21.2	20.8	19.7	18.6	19.1	15.2	13.7	15.3	13.9	10.4	16.5	17.3	52.3	39.1	40.1	36.9	46.9	28.7	25.6	19.4	29.9	33.3	8.0
Blemishes	3.4	5.9	5.1	6.4	5.4	6.2	4.9	4.9	4.5	5.4	10.3	12.2	5.0	11.7	6.1	7.7	8.7	6.9	6.2	10.6	13.0	3.8	11.3	12.2	9.9	15.9	11.8	13.4	9.2	12.7	5.6
Glassiness	44.6	41.7	43.5	46.3	43.3	43.1	43.8	46.5	41.8	39.4	49.7	51.9	42.5	42.6	45.0	45.2	39.8	41.6	43.2	44.5	38.2	38.9	51.3	45.3	41.0	50.6	49.1	51.2	48.3	49.6	8.4
Blackening/Greying	2.9	6.0	3.0	6.1	6.0	4.0	3.1	4.0	4.2	6.5	10.6	10.0	5.3	7.0	6.4	16.1	17.4	11.1	11.4	16.7	8.8	7.7	8.9	16.7	8.6	18.4	15.3	10.2	12.1	14.5	6.0
Mottled	9.0	6.3	3.9	9.5	10.9	4.2	5.3	2.2	5.1	8.0	6.3	8.7	2.9	4.5	4.6	5.2	6.6	4.3	5.0	6.4	30.2	23.9	18.5	34.9	28.8	25.7	28.0	10.0	22.9	28.8	8.2
Surface Disintegrating	10.2	5.2	5.7	13.2	14.1	2.7	3.3	1.7	3.7	7.2	1.6	2.1	3.1	2.3	1.9	0.5	0.5	1.3	1.3	0.5	48.9	34.9	21.2	32.8	47.1	19.5	14.8	5.7	16.7	24.4	8.1
Cut the potato into 2																															
Hardness on 1st Cut	36.3	37.2	38.9	30.0	31.4	40.3	39.3	36.7	32.2	35.8	38.2	28.8	32.8	35.2	33.3	35.4	47.0	37.7	39.3	30.1	33.6	32.3	39.8	34.5	28.8	50.7	46.2	36.9	39.5	35.9	7.3
Mouthfeel/Texture																															
Hardness on 1st bite	27.6	29.2	29.4	19.5	17.9	39.2	35.7	30.8	26.0	24.9	26.6	18.8	23.8	25.3	21.3	30.4	46.2	35.8	38.6	17.3	18.8	18.8	27.4	21.8	16.2	38.4	40.7	31.5	30.5	25.3	7.8
Absorbent	56.9	49.3	46.4	53.0	58.8	29.9	30.3	35.0	37.4	54.3	43.3	41.7	33.6	35.4	37.7	25.6	18.7	23.3	27.4	42.5	73.4	66.7	51.9	67.4	71.8	32.7	37.7	38.6	48.1	59.9	11.0
Waxy	16.4	24.8	22.3	14.6	15.3	36.3	35.0	33.2	29.3	16.3	18.7	30.0	38.5	31.8	31.3	44.8	47.7	41.9	43.6	34.8	4.6	7.9	17.6	11.6	3.3	41.9	33.9	34.6	25.1	13.7	10.6
Floury	48.0	36.3	37.8	48.2	50.3	20.7	25.3	23.5	31.0	45.9	35.9	30.9	20.5	22.7	26.2	11.3	7.5	13.9	12.5	24.2	71.8	62.4	49.3	62.3	67.8	16.6	28.6	25.8	38.9	54.8	11.3
Cloying	45.8	45.6	43.8	51.3	52.9	32.7	35.9	40.7	42.9	44.8	46.5	46.9	39.3	43.3	41.2	30.3	27.3	33.5	34.3	43.5	61.1	60.3	52.5	59.3	61.8	38.9	43.7	42.6	47.3	56.5	9.5
Grainy	25.5	23.0	25.8	24.8	28.0	25.0	25.8	26.7	24.8	21.1	22.2	21.3	23.2	22.9	19.0	22.8	27.3	23.7	25.2	18.4	29.8	29.3	32.3	30.7	33.6	22.2	29.0	25.6	32.0	30.5	NS
Breakdown rate	42.9	42.4	41.2	37.5	42.2	47.7	47.9	43.8	46.3	42.5	44.5	50.6	50.2	49.8	46.7	51.8	53.9	52.6	53.2	50.8	33.4	39.2	38.1	39.4	34.8	42.7	43.1	45.9	35.7	37.8	10.3
Flavour																															
Overall flavour intensity	34.7	37.3	40.9	40.4	41.2	37.9	42.8	41.3	41.4	38.2	40.3	46.9	47.4	44.3	39.9	48.5	50.7	49.9	51.7	52.9	39.7	37.3	37.9	34.1	35.9	39.7	40.0	40.3	35.9	40.4	6.3
Potato	34.0	39.1	37.8	34.4	36.6	32.4	37.2	33.2	37.5	31.6	28.3	29.1	32.1	31.0	28.6	33.4	28.3	31.5	34.4	34.8	30.5	30.3	32.2	30.2	33.0	31.2	35.5	32.3	30.6	32.6	NS
Sweet	8.1	10.2	13.5	14.0	15.3	18.6	17.3	21.8	22.9	18.6	16.9	36.7	36.7	40.0	32.1	42.7	38.5	44.9	43.8	43.6	9.4	11.3	17.0	16.8	14.7	21.2	17.4	20.7	20.6	18.3	8.3
Fishy	1.8	1.1	0.5	3.5	2.5	0.5	1.7	2.5	3.5	2.3	0.7	3.2	3.9	1.6	2.0	3.0	1.3	2.5	2.2	2.3	0.9	2.4	0.5	3.4	4.7	3.9	3.5	0.5	0.6	2.2	NS
Savoury	0.9	1.0	1.0	0.3	0.1	0.4	0.7	1.9	1.2	2.2	1.4	0.6	1.7	0.1	1.0	0.3	2.1	1.2	1.9	1.1	3.1	2.2	3.2	1.0	1.8	0.2	2.0	1.5	1.9	3.0	NS
Earthy	20.2	22.5	21.9	21.7	26.6	21.0	20.7	24.5	23.3	19.8	23.2	18.5	15.5	12.9	15.9	18.8	17.1	19.1	17.5	18.4	22.9	17.2	19.2	20.4	19.3	21.9	21.6	22.9	20.3	20.9	5.9
Sour	18.0	14.9	20.6	18.9	17.6	24.0	22.2	24.6	23.7	25.0	28.4	25.6	27.5	20.2	19.1	28.2	27.2	26.6	26.3	26.5	22.5	23.5	18.9	19.5	20.3	28.2	19.8	22.4	19.3	20.4	7.8
Bitter	13.8	13.9	17.4	12.6	12.8	20.7	20.0	21.4	17.2	18.8	21.7	19.7	22.2	17.2	17.8	21.8	27.0	18.7	18.6	23.6	17.8	19.8	17.5	15.2	13.2	14.7	14.8	13.6	14.1	13.0	NS
Metallic	13.1	12.7	14.9	15.1	14.2	14.8	15.1	16.1	16.7	17.0	20.8	18.1	17.4	14.4	12.5	17.1	16.7	17.5	15.7	17.0	15.3	16.1	11.2	12.0	12.3	16.6	14.5	15.4	13.9	15.0	4.3
Cabbage water	13.9	16.0	19.5	18.4	15.0	22.9	21.6	22.3	20.5	21.7	20.3	25.7	27.2	24.6	20.5	29.4	23.9	27.3	26.3	22.5	16.6	20.3	19.0	16.0	16.9	22.1	24.1	19.0	21.1	25.2	6.3
Off	0.0	0.3	2.4	2.3	1.1	1.8	2.7	3.7	2.6	3.4	5.3	2.3	4.8	2.3	2.4	5.7	3.7	2.9	3.2	2.0	10.5	7.5	5.0	5.6	7.3	3.7	2.5	2.8	4.1	4.8	NS
Aftertaste																															
Overall aftertaste intensity	25.6	29.0	31.5	29.9	26.1	34.6	33.4	35.4	34.3	30.5	34.4	37.2	38.3	33.2	31.4	37.5	39.7	40.2	39.3	38.7	33.4	31.9	29.2	30.7	30.8	33.6	29.7	30.8	27.5	34.9	5.8
Potato	22.2	27.5	27.3	26.9	24.5	21.8	23.5	22.1	23.8	21.6	22.2	21.7	22.0	22.0	19.9	22.7	21.8	23.5	22.3	25.2	23.0	21.6	23.1	24.3	22.5	26.1	24.5	22.7	21.1	25.6	NS
Sweet	4.7	5.7	9.8	9.3	9.4	11.6	12.8	12.2	16.2	13.5	11.5	22.7	26.3	22.2	21.9	30.9	28.3	33.4	30.4	32.0	4.2	7.8	10.7	11.9	8.8	14.3	12.1	12.8	14.8	14.2	7.1
Metallic	13.4	14.4	14.7	15.5	13.0	15.7	16.0	15.8	16.8	15.2	20.1	17.4	16.2	14.3	14.7	15.9	16.5	17.6	15.5	15.9	14.5	14.5	12.7	12.7	13.2	15.2	13.5	14.2	13.4	12.6	NS
Earthiness	14.9	15.1	14.9	15.9	15.9	17.2	16.1	18.9	17.9	14.9	17.0	14.0	12.2	12.2	13.7	15.2	16.4	15.5	14.1	15.0	15.2	15.6	14.9	15.7	14.4	15.7	14.7	15.7	13.3	13.9	NS
Sourness	21.0	18.9	18.7	18.8	17.7	26.1	23.1	24.7	24.3	24.4	27.9	25.6	26.1	21.7	20.2	27.8	25.5	25.3	25.0	31.1	24.0	22.4	19.7	18.6	20.6	26.4	20.4	23.8	20.0	22.2	6.6
Bitter	14.6	17.3	17.4	17.9	16.1	27.8	24.7	24.2	23.0	23.6	27.3	27.5	25.8	18.9	24.3	23.4	27.1	23.7	23.3	27.4	21.1	23.1	19.8	19.0	15.4	21.0	16.9	17.0	18.9	21.7	7.7
Afterfeel																															
Astringent	36.0	33.2	31.3	34.1	35.6	29.2	31.0	30.7	32.7	31.1	34.0	34.9	28.8	32.1	28.0	26.4	28.5	28.6	31.2	32.8	45.8	36.5	35.5	37.0	41.1	30.2	30.4	30.2	32.1	41.4	6.6
Mouthcoating	20.8	23.8	21.2	28.0	25.6	17.5	20.1	22.8	23.3	25.3	21.8	24.8	20.5	19.8	20.2	15.5	13.9	19.1	17.1	23.3	40.5	32.9	31.3	34.0	38.3	18.8	24.2	21.4	25.6	31.2	6.9
Irritant	7.8	5.2	7.1	5.0	6.3	9.8	7.9	9.3	7.7	10.5	13.5	8.1	7.9	7.4	9.1	9.3	9.1	8.5	8.8	8.6	8.7	8.8	7.6	7.2	7.4	9.5	8.1	10.6	7.7	6.6	NS

LSD = Least Significant Differences, products with a difference in mean score higher than the LSD are significantly different in the represented attribute at the 5% significance level.
NS = No significance difference at 95% confidence level

Table A4. Means scores of all samples in Assessment 1

	Estima										Marfona										Maris Piper										
	Untreated					Treated					Untreated					Treated					Untreated					Treated					
	6160/61	6162/63	6164/65	6166/67	6168/69	6170/71	6172/73	6174/75	6176/77	6178/79	6180/81	6182/83	6184/85	6186/87	6188/89	6190/91	6192/93	6194/95	9196/97	6198/99	6200/01	6202/03	6204/05	6206/07	6208/09	6210/11	6212/13	6214/15	6216/17	6218/19	LSD
Aroma																															
Overall aroma intensity	42.2	37.1	35.8	38.5	37.8	39.6	40.0	36.7	42.6	39.8	42.1	39.6	38.9	41.4	42.9	42.2	40.7	39.8	41.1	41.1	39.6	39.0	38.1	39.0	37.2	38.4	37.5	36.5	34.4	38.6	NS
Potato	32.4	29.1	29.4	29.1	28.3	26.3	28.8	25.0	33.2	27.7	31.1	28.5	28.5	29.2	28.5	26.7	24.5	26.9	26.9	25.7	32.0	30.7	31.1	30.3	29.3	31.1	31.2	29.9	27.3	27.8	NS
Fishy	6.7	6.7	4.9	7.1	5.5	9.2	5.4	6.5	3.9	8.6	7.4	6.3	5.2	8.1	10.9	13.6	8.9	7.9	7.8	9.1	4.8	5.5	4.5	3.6	3.7	5.3	5.2	3.7	2.1	6.0	4.7
Savoury	0.3	0.1	0.1	0.1	0.1	0.0	0.1	0.4	0.0	0.1	0.3	0.1	0.1	0.4	0.5	0.2	0.6	0.3	0.5	0.0	0.4	0.1	0.1	0.3	0.1	0.3	0.3	1.2	0.4	0.1	NS
Earthy	26.1	14.8	19.2	15.7	16.1	17.1	21.9	15.1	23.4	18.0	16.1	18.3	16.3	13.5	15.5	14.4	15.9	13.5	15.8	14.5	20.5	18.1	17.0	17.9	17.4	15.7	16.8	16.5	15.4	17.9	5.8
Cabbage water	25.3	25.1	23.5	22.8	21.6	24.6	24.0	21.9	22.8	24.8	21.5	23.0	23.4	27.5	27.4	25.9	26.9	28.6	24.9	26.6	21.2	20.0	18.8	22.6	21.1	19.0	20.9	23.0	21.7	24.4	5.6
Off	0.3	0.8	0.1	0.6	2.2	5.7	0.7	0.6	1.1	2.9	0.9	0.1	0.3	0.5	2.6	3.8	1.8	1.0	5.3	1.6	1.6	0.9	0.9	3.2	1.5	0.8	1.1	0.6	1.6	4.9	NS
Appearance																															
Colour	47.9	50.1	49.1	47.6	42.1	44.7	44.8	42.6	48.0	52.8	67.0	66.6	64.6	65.8	68.4	67.4	65.5	65.8	62.9	69.8	36.4	36.5	31.5	39.0	40.5	34.5	35.6	38.2	35.3	42.9	8.0
Smooth	63.1	63.2	60.8	57.2	68.1	60.5	64.6	63.5	58.9	67.4	73.9	68.6	71.2	72.8	71.4	69.2	73.9	72.7	71.1	76.3	24.9	35.7	20.0	34.1	46.0	26.7	25.9	39.7	19.2	48.2	8.6
Dry	25.8	27.4	30.4	30.3	26.8	30.8	28.3	27.4	33.3	27.0	21.6	26.0	23.0	21.4	20.4	22.5	21.5	20.7	23.7	23.0	52.3	48.7	61.1	48.7	45.2	54.8	59.3	43.9	62.5	45.2	9.5
Blemishes	8.5	2.7	6.8	6.3	4.8	6.6	8.6	5.9	6.5	4.3	7.2	8.2	10.2	5.0	6.5	5.9	10.3	4.7	6.1	4.6	6.6	10.6	9.0	6.3	4.8	5.9	4.8	6.9	5.9	4.3	NS
Glassiness	33.2	36.1	38.8	31.8	36.2	39.9	32.0	34.6	35.4	39.0	40.5	41.9	39.7	38.8	37.5	35.9	36.2	38.4	39.2	42.5	32.8	35.8	33.6	36.8	38.0	28.9	29.9	37.6	31.1	32.6	NS
Blackening/Greying	11.6	7.9	4.9	6.8	4.3	6.6	4.0	4.6	11.3	8.6	10.2	8.6	8.9	6.8	8.4	10.2	6.6	5.8	4.7	7.7	9.4	11.3	9.6	10.2	9.2	10.0	11.2	8.7	12.3	9.1	NS
Mottled	10.7	10.7	12.7	15.0	11.5	9.1	13.8	8.2	11.7	10.1	6.2	7.2	6.4	7.2	6.5	6.3	6.9	7.0	6.9	6.1	33.4	25.6	33.7	27.9	24.9	32.7	33.1	29.5	36.9	20.0	9.1
Surface Disintegrating	6.5	10.2	16.2	10.9	3.6	7.6	6.9	8.3	13.4	4.2	1.0	3.3	2.1	1.9	1.6	1.9	1.6	2.9	1.6	2.2	39.7	34.7	52.8	31.8	29.6	43.8	49.1	31.9	52.0	24.3	8.4
Cut the potato into 2																															
Hardness on 1st Cut	32.7	26.0	27.7	28.8	25.9	28.9	29.6	30.1	31.0	30.6	30.9	29.2	36.2	25.1	23.5	26.9	27.1	27.7	23.9	25.7	31.8	31.7	28.0	31.7	31.1	31.1	30.6	31.0	32.0	29.8	4.5
Mouthfeel/Texture																															
Hardness on 1st bite	22.0	19.0	19.0	20.2	17.8	19.7	19.6	19.1	21.9	17.8	22.2	20.5	30.6	18.6	16.1	21.0	21.2	19.5	16.9	18.6	16.1	20.8	17.3	19.3	21.5	17.9	21.3	16.5	17.6	23.1	4.4
Absorbent	43.1	41.8	46.5	43.2	36.0	42.2	44.3	42.6	45.2	39.2	30.4	34.2	27.0	27.9	27.7	32.3	28.2	33.5	29.8	28.3	57.2	60.3	64.3	61.1	53.0	62.0	66.6	56.7	63.6	45.4	10.1
Waxy	21.1	29.7	18.9	25.6	29.9	27.8	25.8	25.0	26.3	33.9	39.4	37.1	41.5	43.4	45.6	40.9	43.8	43.6	40.2	46.8	12.7	17.5	9.2	13.2	19.0	12.4	9.7	14.7	7.1	28.9	9.4
Floury	39.4	30.2	41.4	35.5	22.7	34.1	35.7	32.9	38.5	27.3	14.8	21.8	15.6	14.1	10.3	17.9	14.0	17.4	13.6	9.8	51.8	53.2	62.2	55.7	44.1	57.3	63.9	54.1	60.9	38.4	11.5
Cloying	41.2	40.6	41.8	36.2	33.1	39.0	38.3	38.6	41.6	39.8	25.8	34.2	25.5	26.8	25.1	30.5	28.7	31.8	30.1	28.2	48.8	48.4	52.8	52.4	46.5	50.9	52.2	48.4	54.1	41.5	9.8
Grainy	28.8	29.2	29.5	30.9	23.2	25.9	32.1	28.4	29.7	23.2	21.6	25.1	25.7	22.3	20.2	21.9	22.8	21.1	23.2	23.3	32.1	35.2	33.4	36.5	33.3	37.7	36.4	31.3	37.7	29.3	10.1
Breakdown rate	43.5	48.3	43.7	47.5	51.2	44.2	46.3	44.5	41.5	45.4	53.8	52.9	51.5	55.3	58.2	53.7	56.6	55.1	56.4	59.4	34.5	35.8	29.3	35.2	39.6	32.6	29.5	35.9	27.2	39.7	9.3
Flavour																															
Overall flavour intensity	43.3	40.4	41.9	42.2	40.7	41.9	42.4	41.8	44.4	45.8	50.9	48.2	46.5	49.6	53.2	52.1	51.2	50.7	50.7	53.4	39.0	39.5	39.9	41.2	39.9	38.9	38.5	37.9	40.0	43.8	6.4
Potato	35.0	34.6	36.7	35.4	34.8	33.6	35.9	32.7	37.0	32.7	33.3	34.4	33.9	32.4	32.2	33.5	30.9	31.2	32.0	31.5	36.9	36.0	34.9	37.8	33.2	35.3	31.7	33.7	35.1	31.7	NS
Sweet	9.5	10.6	9.1	14.4	12.6	13.6	9.5	13.4	11.8	15.3	34.4	31.1	25.3	37.6	42.1	39.1	42.5	41.2	41.7	46.4	5.9	8.6	5.3	5.6	13.6	4.9	4.3	11.2	9.8	21.6	8.4
Fishy	2.1	2.1	2.1	3.5	1.6	2.6	2.8	1.6	0.7	2.2	0.8	1.6	0.6	1.8	2.3	5.2	3.0	3.1	1.9	1.3	1.1	0.9	1.6	1.5	0.7	1.3	1.7	1.1	1.7	3.2	NS
Savoury	0.3	0.3	1.0	0.0	0.2	0.1	0.3	0.2	0.1	0.0	0.0	0.1	0.3	0.0	0.0	0.3	0.7	0.1	0.1	0.1	0.1	0.8	0.1	0.1	1.0	0.6	0.3	0.1	0.9	0.1	NS
Earthy	24.5	19.9	25.4	18.7	21.0	22.1	22.9	20.2	24.5	20.1	17.9	17.7	18.6	16.9	16.5	20.3	17.1	17.6	17.4	18.2	22.6	21.9	22.1	25.0	20.8	20.2	21.9	18.2	20.2	18.1	NS
Sour	18.2	21.2	17.9	17.4	21.8	20.9	19.9	15.2	16.3	17.9	21.2	16.0	17.3	24.0	23.0	24.7	21.7	24.4	19.8	21.9	14.0	19.2	18.6	21.8	16.8	12.5	16.2	16.6	17.9	17.1	NS
Bitter	15.6	15.8	16.5	10.1	15.2	16.6	18.1	14.8	15.1	14.3	13.7	13.4	10.7	12.6	15.1	17.0	17.2	22.3	15.8	15.8	9.6	14.3	14.5	15.7	13.8	14.9	13.3	13.3	11.5	13.7	NS
Metallic	12.5	11.0	11.4	9.3	11.4	13.2	13.1	9.8	10.4	10.6	11.4	10.7	10.1	11.2	11.6	13.0	12.8	14.1	12.9	13.2	9.5	9.7	11.0	12.2	9.4	11.0	12.1	10.7	11.5	9.8	NS
Cabbage water	18.8	21.5	20.6	18.6	21.7	22.8	22.5	22.1	18.9	24.3	22.0	21.9	20.0	26.4	31.1	28.6	30.1	29.9	25.9	28.7	14.7	15.3	16.1	15.8	16.8	18.1	15.5	17.5	17.6	23.6	5.5
Off	4.2	2.6	2.5	0.8	1.3	4.3	3.2	1.1	3.6	4.0	1.4	2.1	2.2	2.0	2.5	4.7	3.0	1.5	4.6	3.7	1.3	0.8	2.0	3.1	1.6	1.0	1.7	1.2	6.4	4.3	NS
Aftertaste																															
Overall aftertaste intensity	34.4	33.8	36.0	36.3	35.2	36.5	35.9	34.4	34.6	35.7	35.5	36.3	34.8	40.9	40.5	40.6	38.7	40.5	40.7	41.3	28.8	34.7	33.0	35.9	32.6	33.5	32.0	33.9	35.3	35.0	5.3
Potato	26.4	23.2	29.1	27.6	26.8	26.9	27.8	25.7	27.1	22.7	21.8	23.7	22.8	23.8	22.6	24.2	21.8	22.3	20.9	22.4	25.6	29.3	27.3	27.8	25.7	26.3	23.8	25.3	25.3	26.5	4.9
Sweet	5.0	8.0	5.5	11.6	6.5	8.2	5.5	7.7	6.5	10.5	21.4	18.6	17.0	26.7	30.3	27.0	29.6	28.8	31.0	32.5	2.9	4.2	2.7	3.2	7.8	3.0	3.6	7.7	7.0	16.1	6.4
Metallic	10.5	10.8	12.6	10.5	11.3	13.4	14.3	10.3	9.7	12.4	10.0	8.8	9.1	11.9	10.5	12.9	12.6	13.4	13.2	13.0	10.2	11.5	12.1	12.6	8.4	11.1	10.8	13.1	12.6	9.5	NS
Earthiness	17.7	14.0	17.1	14.6	14.2	16.1	16.7	15.1	17.2	15.2	13.8	12.1	11.9	13.0	13.8	13.1	13.1	14.2	14.1	13.3	14.5	18.0	15.3	18.8	13.0	14.2	16.2	12.8	13.8	14.8	4.0
Sourness	18.9	24.7	22.6	22.6	24.5	25.6	24.0	20.1	20.2	20.6	21.5	19.0	20.5	24.2	25.7	26.1	25.2	26.4	24.4	26.7	18.1	22.1	22.8	25.5	18.8	16.7	18.5	20.2	20.4	23.6	6.3
Bitter	16.1	19.6	21.0	18.8	20.2	22.4	22.3	21.2	19.0	22.1	16.7	19.9	21.2	20.0	20.3	23.0	21.4	28.5	24.2	24.5	14.8	18.6	17.4	19.0	18.3	17.1	21.1	20.2	18.4	21.6	NS
Afterfeel																															
Astringent	37.2	38.6	40.1	40.3	38.9	36.9	40.2	34.2	40.6	34.6	31.3	30.5	29.4	32.6	31.1	38.0	31.7	34.7	33.3	31.6	42.2	43.9	46.8	46.2	38.2	45.5	45.2	41.7	46.1	40.2	7.1
Mouthcoating	21.9	23.6	25.5	23.7	22.1	25.1	23.8	22.5	23.8	22.4	16.5	18.0	17.1	16.1	16.7	19.7	15.5	19.3	18.8	16.7	29.7	29.1	33.3	30.6	26.4	33.2	30.8	30.1	32.7	27.1	6.1
Irritant	13.3	11.2	12.5	11.6	13.9	13.7	17.9	14.3	15.8	14.3	10.2	9.3	11.0	11.2	11.6	15.0	16.9	15.3	16.5	16.5	12.4	12.7	12.7	16.8	11.1	12.1	17.1	18.3	16.1	15.8	NS

LSD = Least Significant Differences, products with a difference in mean score higher than the LSD are significantly different in the represented attribute at the 5% significance level. NS = No significance difference at 95% confidence level

TABLE A5. MEANS SCORES OF ALL SAMPLES IN ASSESSMENT 2

9.1.8.1. Aroma

Assessors evaluated 7 attributes for the aroma category (Table A4 and A5). A graphical representation of the significant attributes is shown in Figure A1. Significant differences were identified on the potato, fishy and earthy attributes in the first assessment and cabbage water, fishy and earthy were significant in the second assessment.

9.1.8.1.1. Potato

Untreated Estima generally had the strongest potato aroma; untreated Marfona had the weakest. This trend was only identified in the first assessment. No difference was identified between the ethylene treated varieties for this attribute. However all potatoes appeared very slightly stronger in potato aroma at the second assessment.

9.1.8.1.2. Fishy

Treated potatoes appeared very slightly fishier than the untreated variants in both assessments. There were no trends observed within any of the untreated or treated groups whilst increasing the amount of CO_2.

9.1.8.1.3. Earthy

Estima potatoes showed the strongest earthy aroma notes, whilst Marfona was weakest in this aroma. In assessment 1, the untreated Estima potatoes were all earthier than the Estima potatoes which had the ethylene treatment; this trend was inversed for the Marfona potatoes, where treated potatoes were perceived earthier in aroma. No trends were observed within the varieties and the treatment conditions.

9.1.8.1.4. Cabbage water

There were slight levels of cabbage water aroma notes present in all the potato samples. Overall, in both assessment 1 and 2, the Maris Piper variety displayed the weakest cabbage water aroma levels.

9.1.8.1.5. Other aroma attributes

Each of the evaluated potatoes had moderate overall aroma intensity, mainly defined by the attributes mentioned above. No significant savoury or off notes were identified.

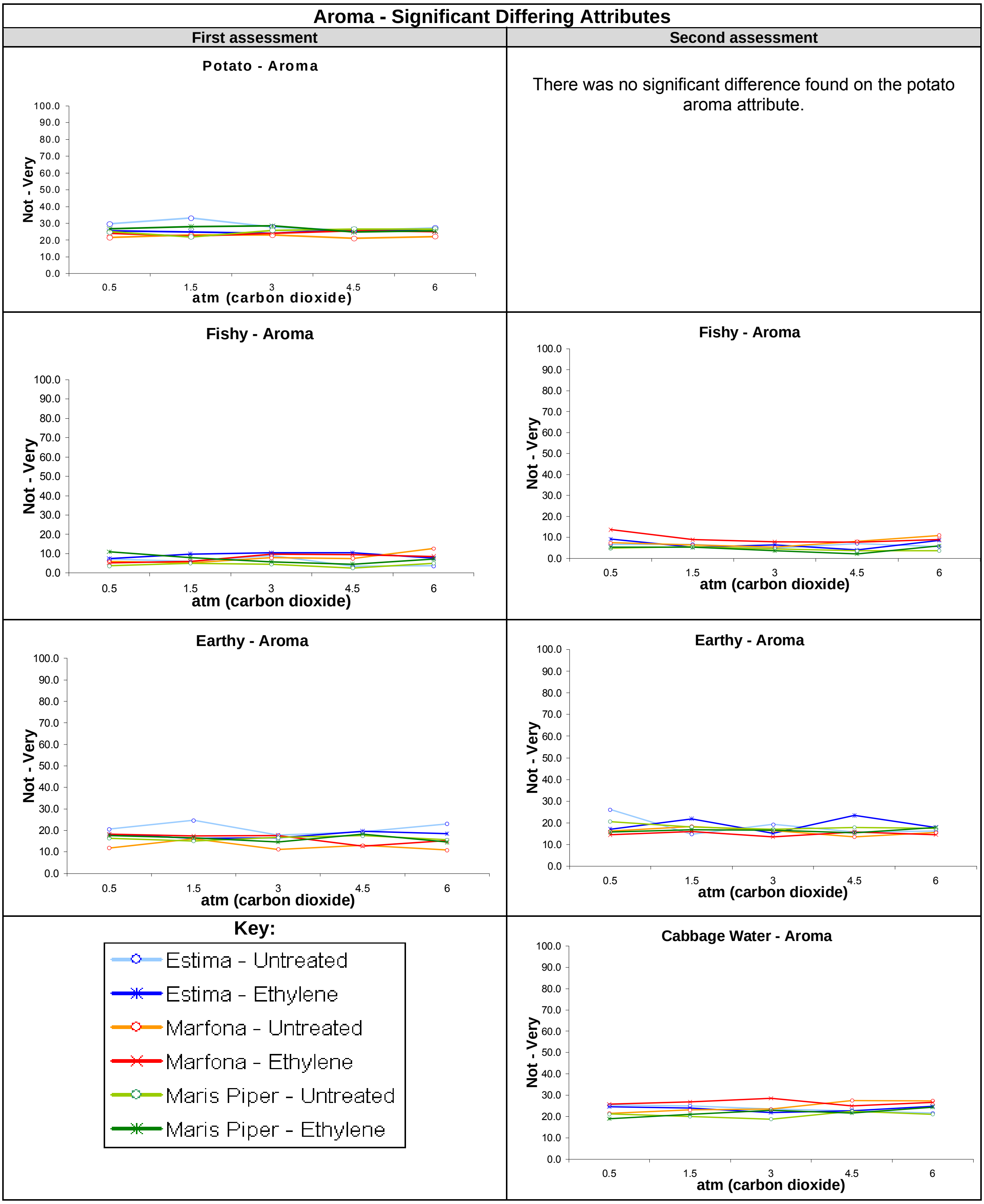


FIGURE A1 - MEAN SCORES FOR AROMA ATTRIBUTES

9.1.8.2. Appearance

Eight attributes were assessed in the appearance category (Table A4 and A5). All of the attributes displayed a significant difference in assessment 1, whereas in assessment 2 all attributes apart from blemishes, glassiness and blackening/greying displayed a significant difference.

9.1.8.2.1. Colour

In assessment 1, within each variety all of the treated potatoes were identified as being darker in colour than their corresponding untreated potato. However, no trend within varieties was seen between the treated and untreated samples in assessment 2. In both assessments, the Marfona variety was identified as the darkest and the Maris Piper as the lightest. The level of carbon dioxide could have had an effect on the first evaluated potatoes; an increase in colour was identified between 0.5, 1.5 & 3.0 atm carbon dioxide.

9.1.8.2.2. Smooth appearance

In assessment 1, within each variety all of the treated potatoes were identified as being smoother, than their corresponding untreated potato. In assessment 2 no trend within varieties was seen between the treated and untreated samples. Marfona potatoes were identified as having the smoothest appearance, closely followed by the Estima variety. In assessment 1 potatoes exposed to 3.0 atm carbon dioxide were identified as smoother than those exposed to lesser or higher levels of carbon dioxide. In assessment 2 the highest level of carbon dioxide (6.0 atm) resulted in the smoothest potato.

9.1.8.2.3. Dry appearance

Untreated Maris Piper (assessment 1) and treated and untreated Maris Piper (assessment 2) appeared most dry. No specific trend in treatment or carbon dioxide level was identified for this attribute.

9.1.8.2.4. Blemishes

Only very few blemishes were present in any of the potato samples. In assessment 1 it was seen that the Maris Piper potatoes were overall the most blemished whilst the Estima potatoes were the least.

9.1.8.2.5. Glassiness

Some glassiness was present in all of the samples, no real trend could, however, be identified based on variety, storage condition or carbon dioxide level.

9.1.8.2.6. Blackening/greying

Only small levels of blackening/greying were identified for the evaluated potatoes. Assessment 2 showed a decrease in blackening/ greying in comparison with assessment 1 for Marfona and Maris Piper.

9.1.8.2.7. Mottled appearance

Maris Piper had the most mottled appearance. Only small levels were identified for Marfona and Estima varieties. Within the Estima potatoes the untreated to corresponding treated potatoes displayed less mottling.

9.1.8.2.8. Disintegrating surface

Maris Piper (untreated in assessment 1 and both storage conditions for assessment 2) was identified to disintegrate most. The surface of Marfona potatoes did not really disintegrate at all, similarly ethylene treated Estima potatoes disintegrated only very slightly.

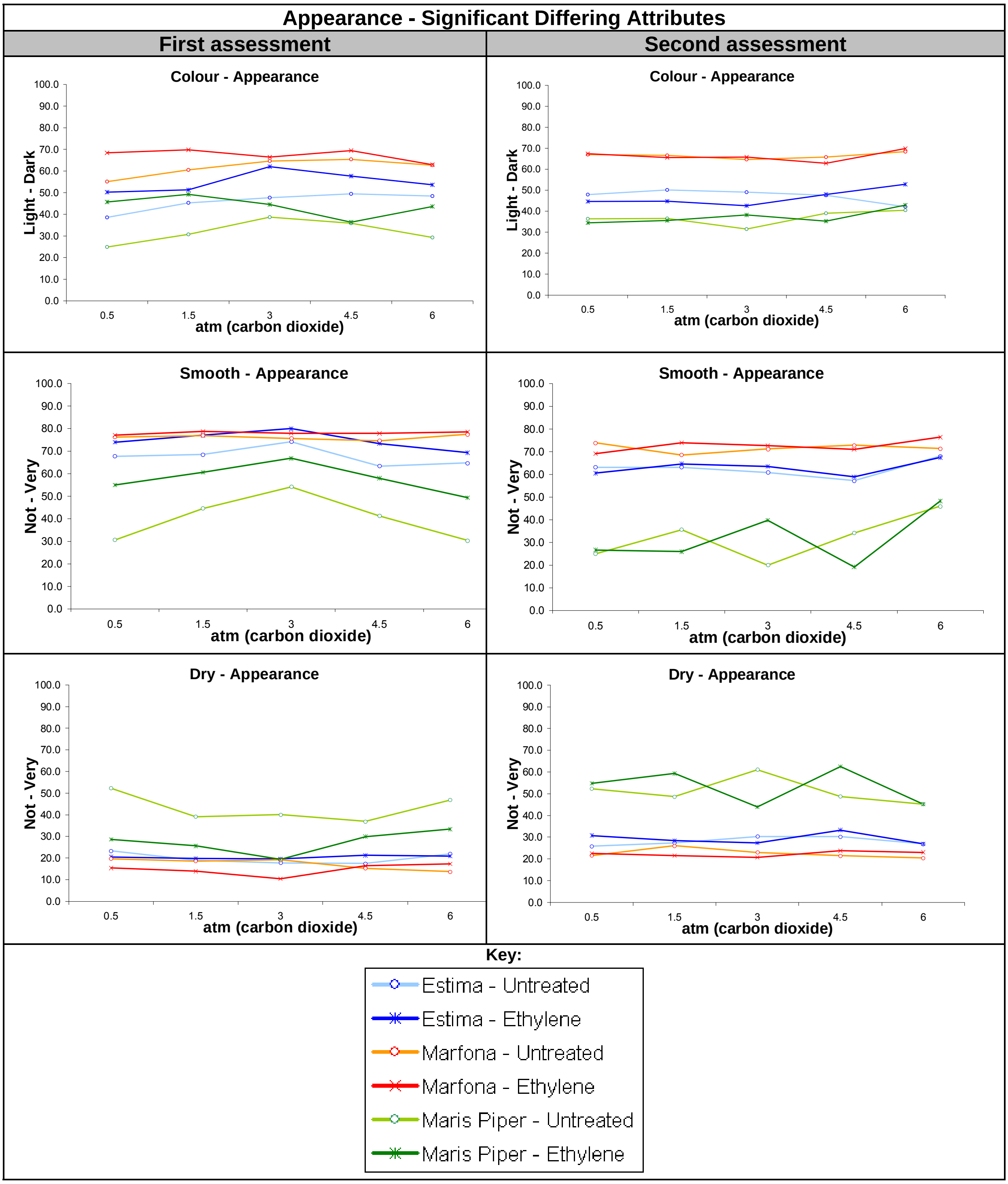
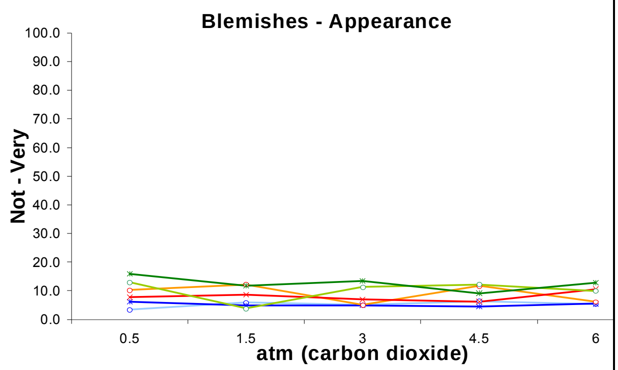
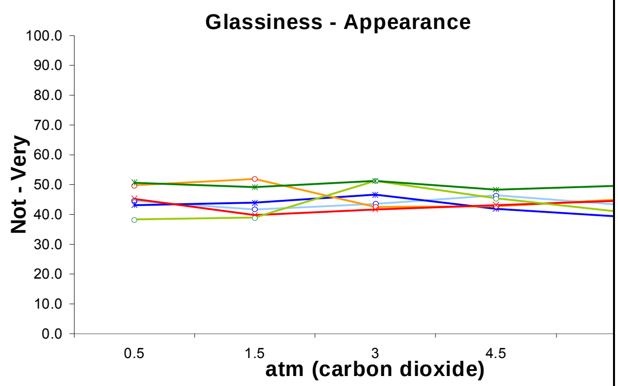
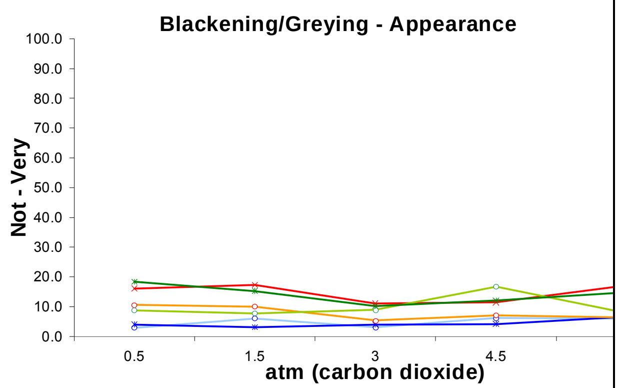


FIGURE A2 - MEAN SCORES FOR APPEARANCE ATTRIBUTES (1)

Appearance - Significant Differing Attributes	
First assessment	**Second assessment**
	There was no significant difference found on the blemishes attribute.
	There was no significant difference found on the glassiness attribute.
	There was no significant difference found on the Blackening / Greying attribute.

Key:

FIGURE A3 - MEAN SCORES FOR APPEARANCE ATTRIBUTES (2)

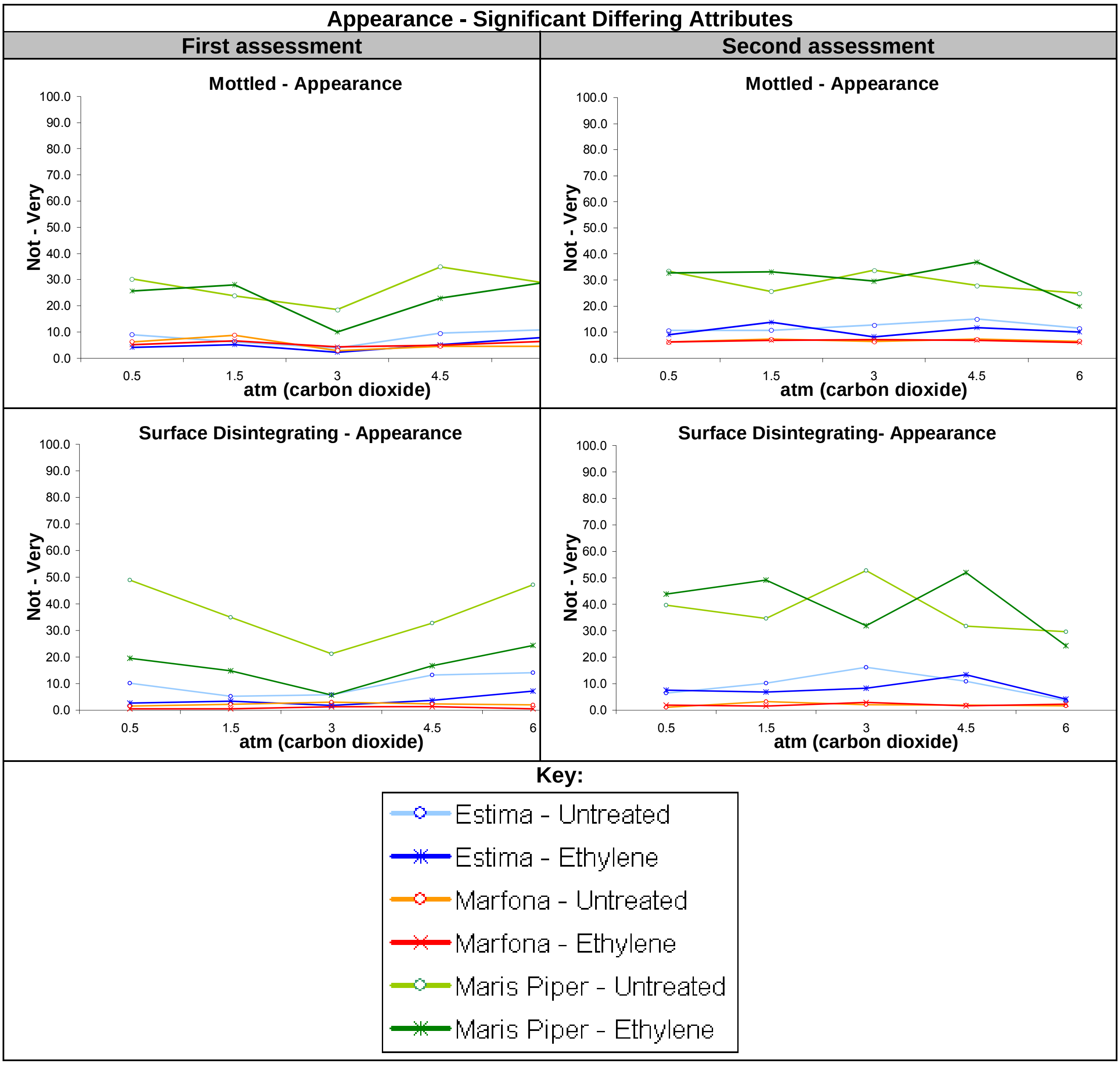


FIGURE A4 - MEAN SCORES FOR APPEARANCE ATTRIBUTES (3)

9.1.8.3. Texture

Eight attributes were assessed in the texture category (Table A4 and A5). Of these seven were significantly discriminating attributes in assessment 1, and all were significant in assessment 2. The only attribute not showing a significant difference in the first assessment was grainy.

9.1.8.3.1. Hardness on 1st cut

Within assessment 1, the treated potato appeared to be slightly harder to cut than the equivalent untreated potato for the Estima and Maris Piper variants. Within the 2nd assessment point there is little variation in hardness within potatoes between treatment conditions.

9.1.8.3.2. Hardness on 1st bite

Generally across the samples in assessment 1, the treated potatoes were slightly harder than their corresponding untreated ones. However, there was little variation in hardness within potatoes between treatment conditions in assessment 2.

9.1.8.3.3. Absorbency

In assessment 1, within each potato variant, the treated potato was less absorbent than its untreated equivalent. In assessment 2 the treated potatoes had a similar (moderate to moderately high) level of absorbency as their corresponding untreated potato. Maris Piper untreated was the most absorbent variety, in assessment 1. Both ethylene treated and untreated Maris Piper potatoes had the highest levels of absorbency in assessment 2. The Marfona variety showed the least absorbency, although a moderate degree.

9.1.8.3.4. Waxy

Generally, within each potato variant, the treated potato appeared to be waxier than its untreated equivalent. Potatoes stored at higher carbon dioxide levels appeared very slightly waxier in assessment 2. This trend was not observed in assessment 1, where untreated potatoes were waxiest around 3.0 atm carbon dioxide and treated potatoes at the lowest level of carbon dioxide (0.5 atm). Marfona potatoes were the waxiest, whilst untreated Estima and untreated Maris Piper were least waxy.

9.1.8.3.5. Floury

In assessment 1, within each potato variant, the untreated potato appeared flourier than its treated equivalent. This, however, is not the case in assessment 2. Maris Piper was the flouriest potato, whilst Marfona scored relatively low on the floury attribute. Assessment 1 showed a higher level of flouriness when potatoes were stored under higher carbon dioxide levels (6.0 atm), however, at the same carbon dioxide level assessment 2 showed the least floury potatoes.

9.1.8.3.6. Cloying

All samples were identified as relatively cloying with Maris Piper as the most cloying variant. In assessment 1 within each potato variant, the untreated potato appeared more cloying than its treated equivalent. This trend however is not seen in assessment 2. Carbon dioxide did not appear to influence the cloyingness of the potatoes.

9.1.8.3.7. Grainy

Very little difference was apparent across the potato variants and treatment conditions; Maris Piper potatoes appeared most grainy.

9.1.8.3.8. Breakdown rate

In assessment 1 treated potatoes had a faster breakdown rate than their corresponding untreated variant; this trend was not observed in assessment 2. The potato variant with the quickest breakdown rate was Marfona, whilst Maris Piper broke down the slowest.

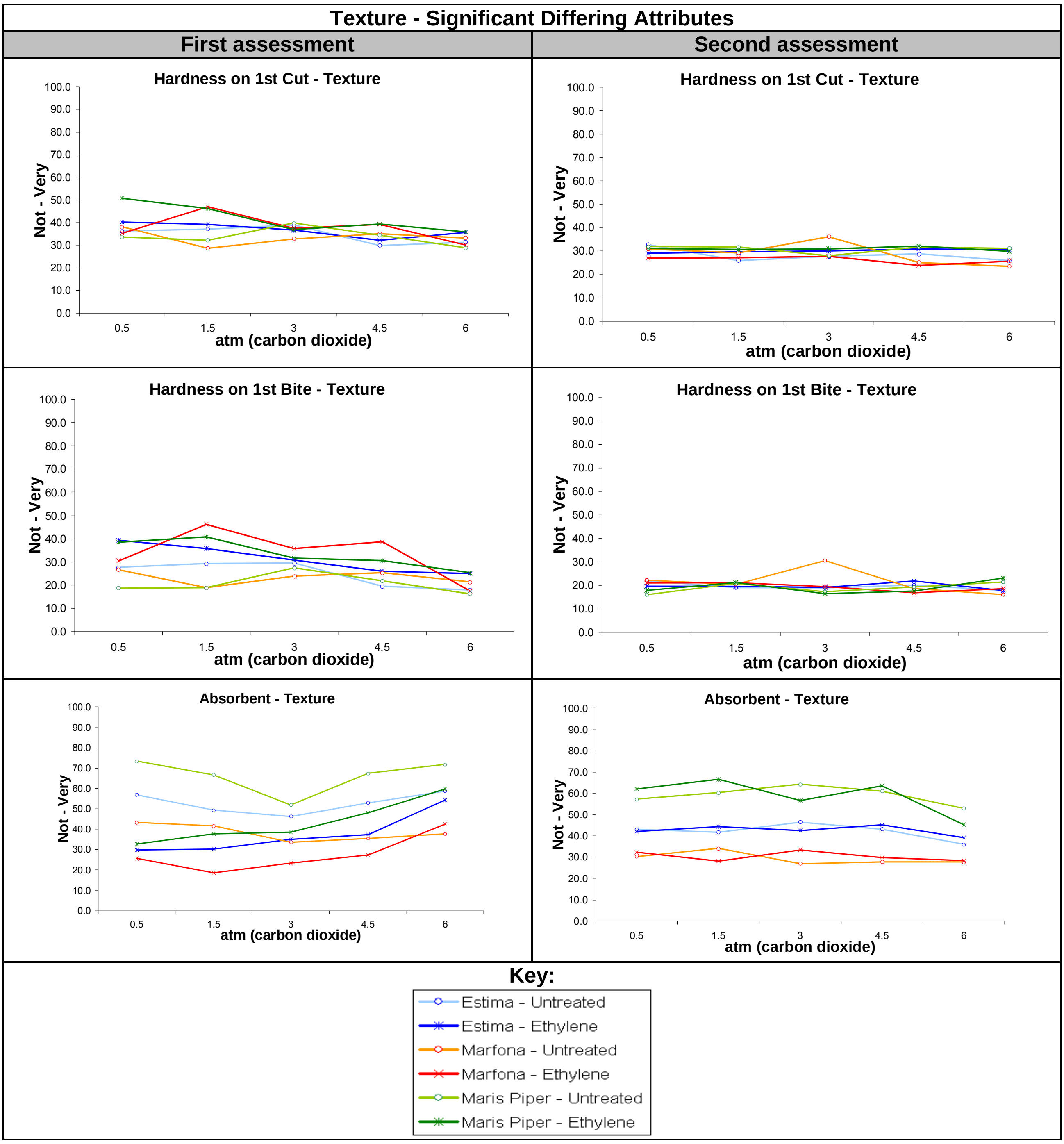


FIGURE A5 - MEAN SCORES FOR TEXTURE ATTRIBUTES (1)

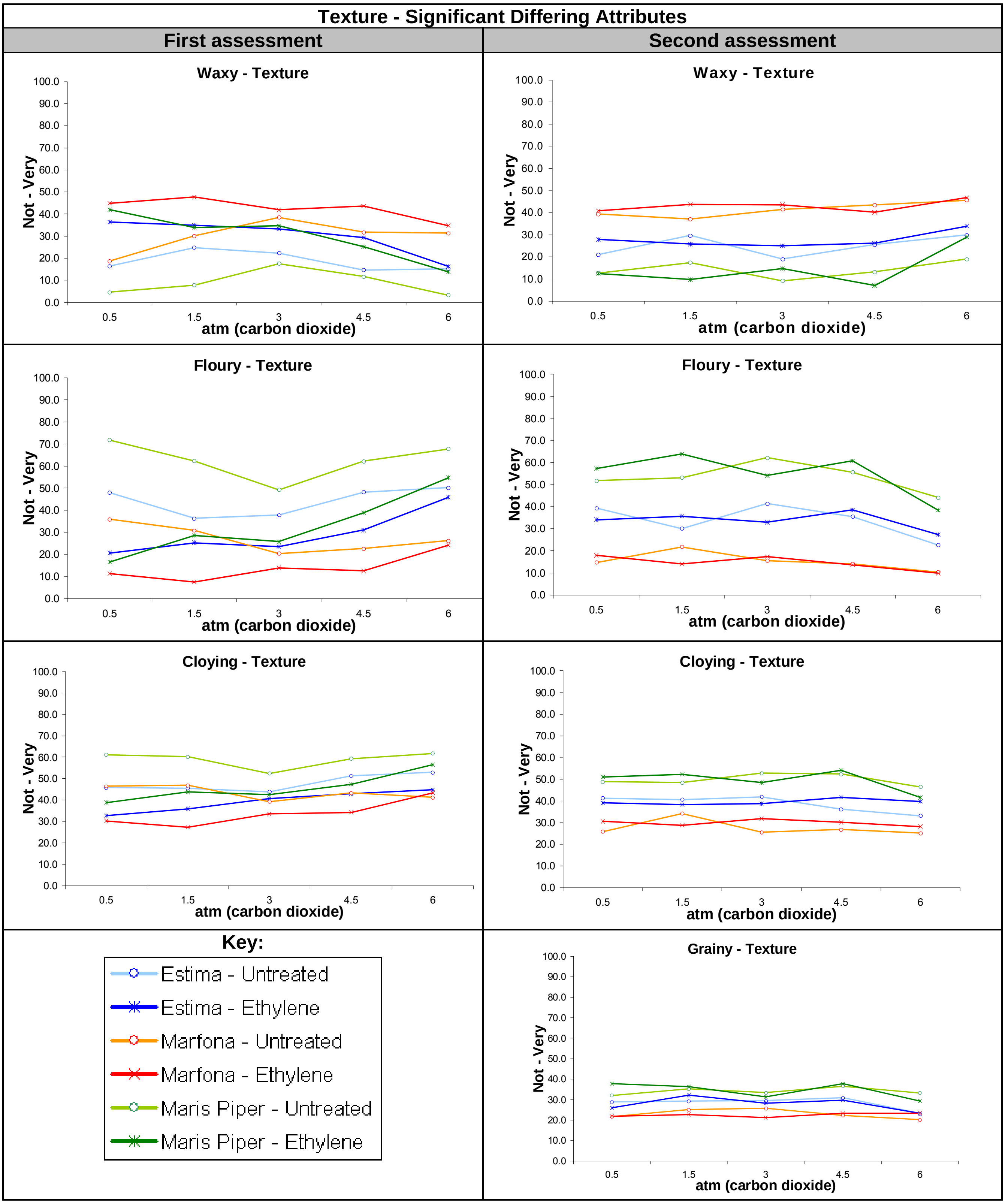


FIGURE A6 - MEAN SCORES FOR TEXTURE ATTRIBUTES (2)

Texture - Significant Differing Attributes

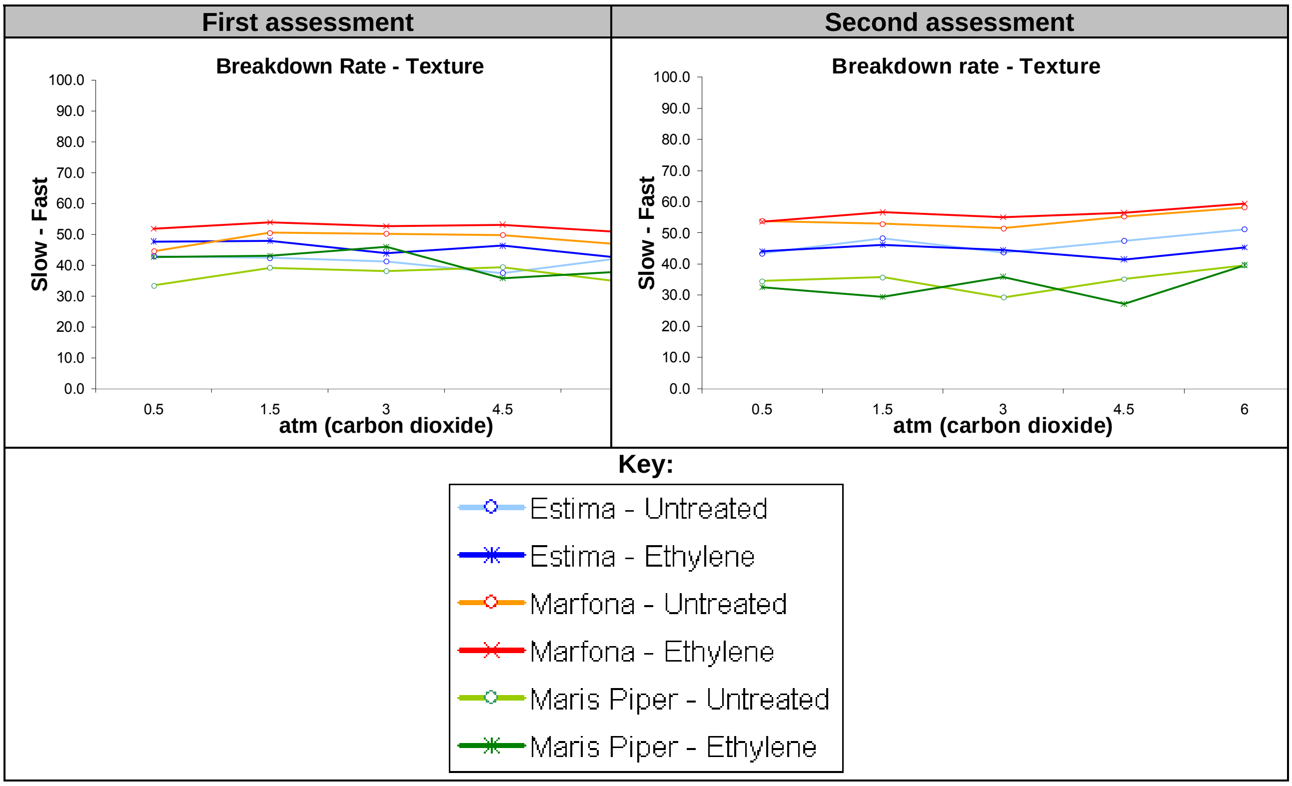


FIGURE A7 - MEAN SCORES FOR TEXTURE ATTRIBUTES (3)

9.1.8.4. Flavour

Eleven attributes were assessed in the flavour category (Table A4 and A5). In assessment 1 six were significantly discriminating attributes; overall flavour intensity, sweet, earthy, sour, metallic and cabbage water. In assessment 2 only three attributes were significantly different; overall flavour intensity, sweet and cabbage water.

9.1.8.4.1. Overall flavour

All potatoes had moderate overall flavour intensity, with the untreated variants generally weaker in overall flavour than the corresponding ethylene treated potatoes. The Marfona potatoes were very slightly stronger in overall flavour intensity than the other two varieties.

9.1.8.4.2. Sweetness

The Marfona potatoes were perceived as relatively sweet. However, this sweetness was present to a much lesser degree for the Estima and Maris Piper varieties and the sweetness of these two varieties decreased slightly between assessment 1 and assessment 2. In assessment 1, the sweeter potatoes were the ones which had been treated. This sweetness trend is also apparent in assessment 2 for the Marfona variant and to a degree with the Maris Piper potatoes at the higher atmospheric carbon dioxide levels.

9.1.8.4.3. Earthy

All potatoes had a slight to moderate earthy note identified. No real trend however was observed between different varieties or storage conditions.

9.1.8.4.4. Sour

All potatoes also had a sour taste identified. A trend was observed in the Estima and Marfona varieties where the treated potato was sourer than the corresponding untreated potato stored in the same atmospheric conditions in assessment 1.

9.1.8.4.5. Metallic

Slight metallic notes were identified in all the potatoes.

9.1.8.4.6. Cabbage water

A cabbage water flavour attribute was present at a slight to moderate level and was a discriminating attribute in both assessment 1 and 2. Within the Maris Piper and Estima varieties the untreated potatoes yielded a weaker cabbage water element than the corresponding treated potato. This trend was not as clearly present for the Marfona variety.

The potatoes were mainly described as potato, earthy, sour and cabbage water flavoured, with a greater or lesser degree of sweet, bitter and metallic notes.

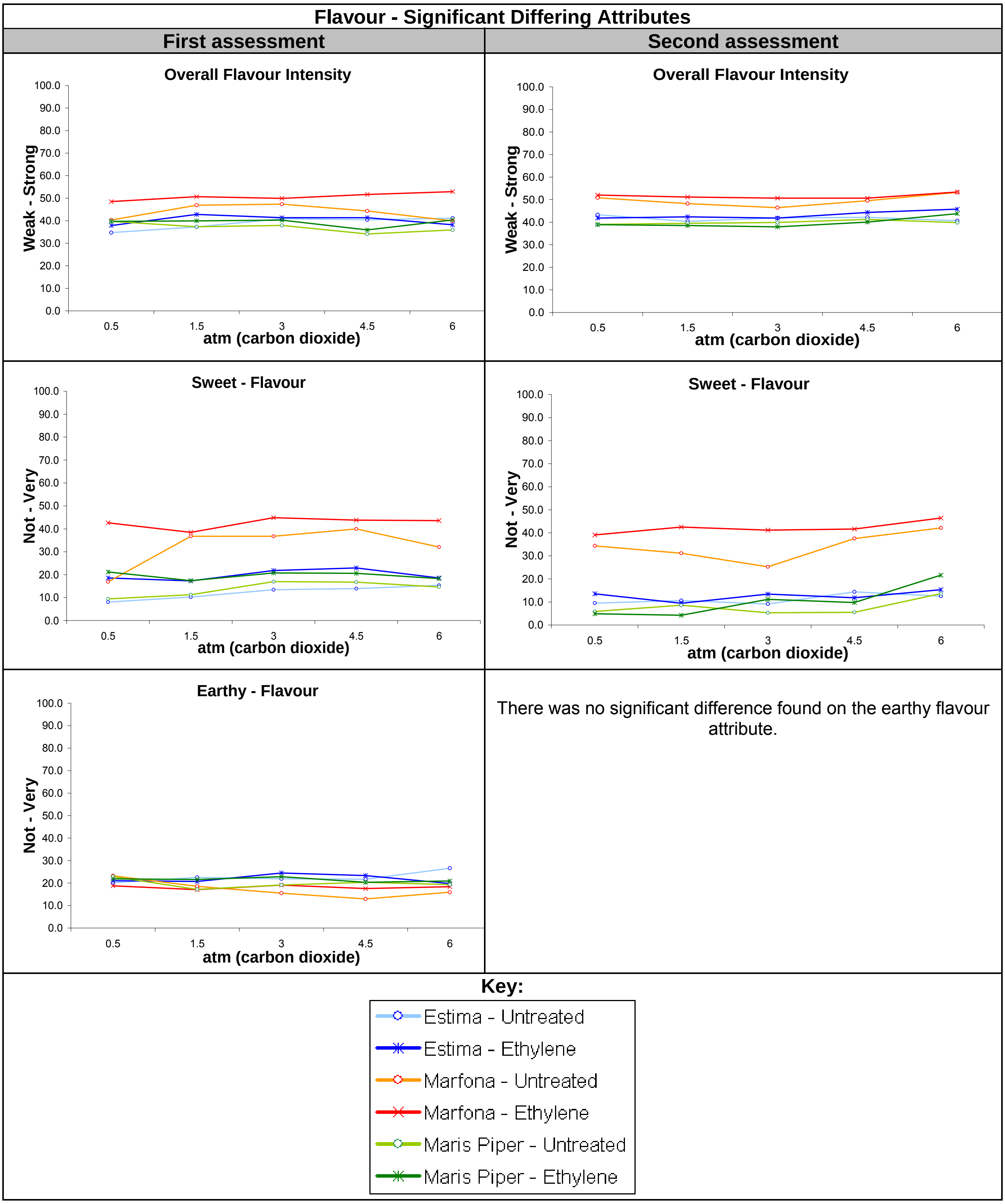
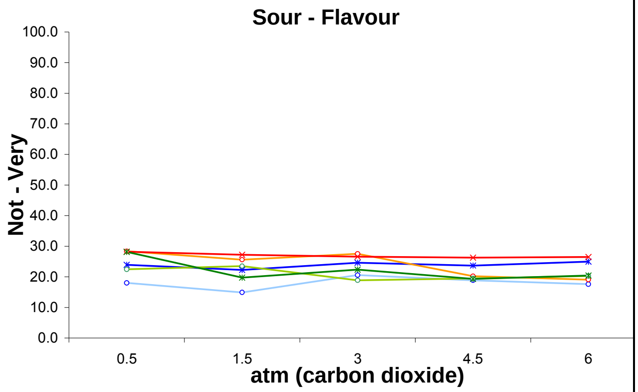
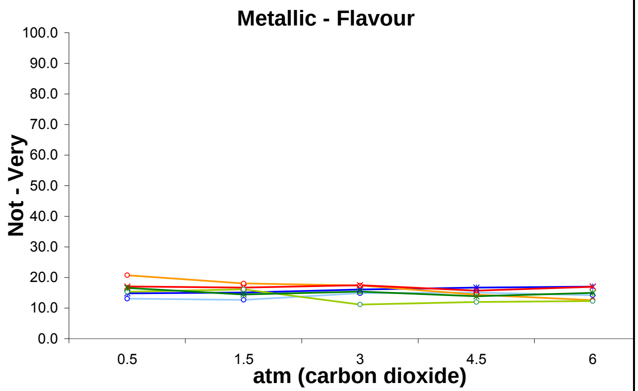
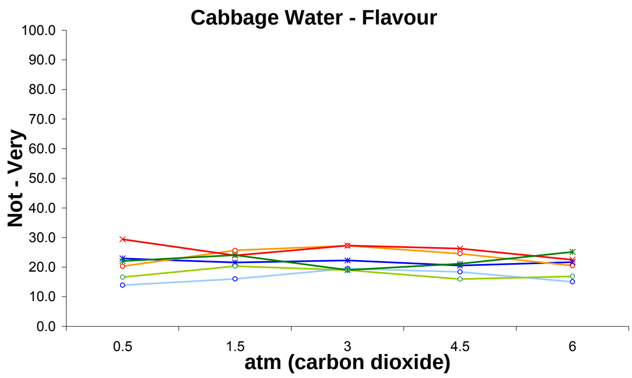
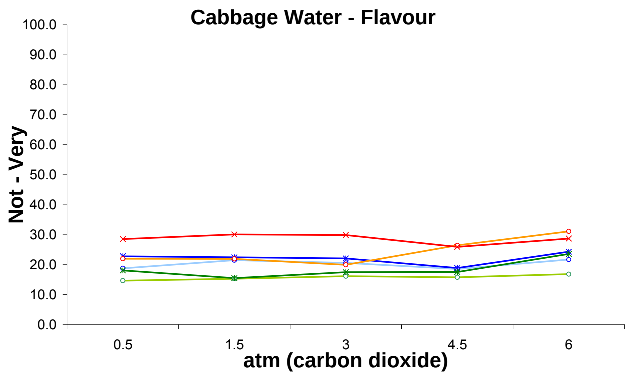


FIGURE A8 - MEAN SCORES FOR FLAVOUR ATTRIBUTES (1)

Flavour - Significant Differing Attributes	
First assessment	**Second assessment**
	There was no significant difference found on the sour taste attribute.
	There was no significant difference found on the metallic flavour attribute.
	

Key:

- Estima - Untreated
- Estima - Ethylene
- Marfona - Untreated
- Marfona - Ethylene
- Maris Piper - Untreated
- Maris Piper - Ethylene

FIGURE A9 - MEAN SCORES FOR FLAVOUR ATTRIBUTES (2)

9.1.8.5. Aftertaste

Seven attributes were assessed in the aftertaste category (Table A4 and A5). Of these, in assessment 1, four were attributes where a significant difference was identified whereas in assessment 2 there were five significant attributes.

9.1.8.5.1. Overall aftertaste

All potatoes had moderate overall aftertaste intensity, with the untreated variants generally weaker in overall aftertaste than the corresponding ethylene treated potato. The Marfona potatoes were very slightly stronger in overall aftertaste intensity than the other two varieties.

9.1.8.5.2. Potato

In assessment 1 the potato attribute was not significant whereas in assessment 2 it was. The Marfona untreated and ethylene treated potatoes recorded a lower intensity of potato aftertaste than either the Estima or Maris Piper.

9.1.8.5.3. Sweetness

The Marfona potatoes were perceived as relatively sweet and this sweetness was present to a much lesser degree for the Estima and Maris Piper varieties. In assessment 1 across the potato varieties, the treated potatoes were sweeter when compared. This trend is also apparent in assessment 2.

9.1.8.5.4. Earthy

All potatoes had a slight earthy note but no real trend was apparent.

9.1.8.5.5. Sour

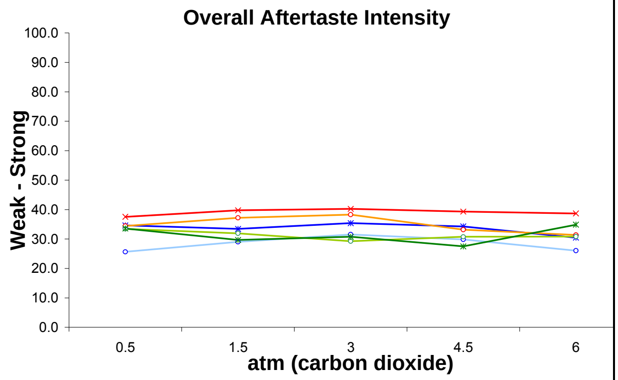
In assessment 1 a trend was seen in the Estima and Marfona varieties where the treated potato was sourer than the corresponding untreated potato stored in the same atmospheric conditions. This trend is observed in assessment 2 with the Marfona variety.

9.1.8.5.6. Bitter

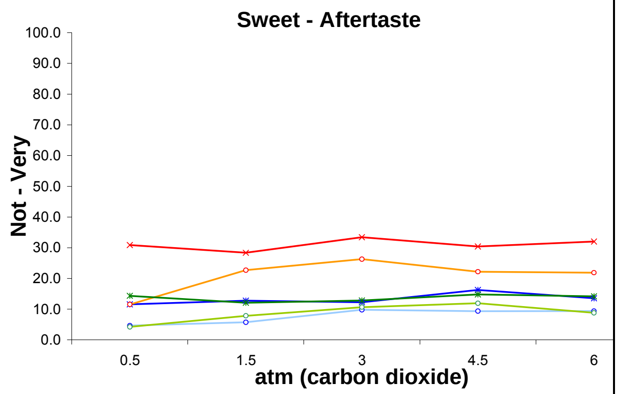
In assessment 1, within the Estima variety the bitter aftertaste intensity was greater if sprout suppressant had been applied and was, therefore, more bitter than the corresponding untreated potato.

Aftertaste - Significant Differing Attributes

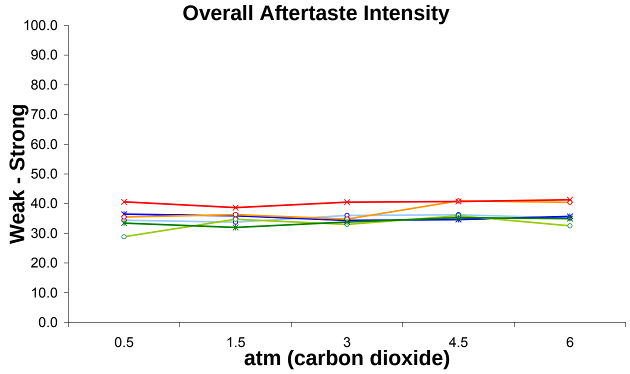
First assessment

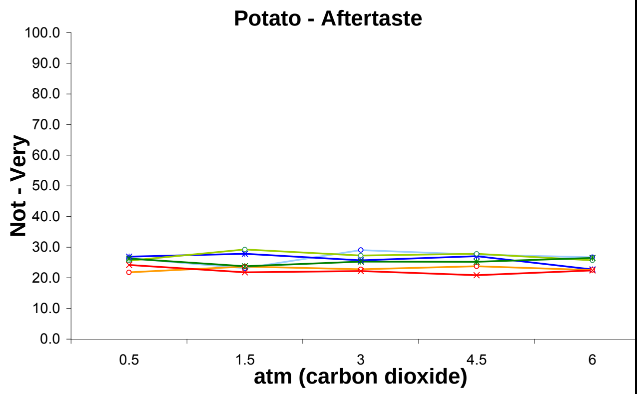


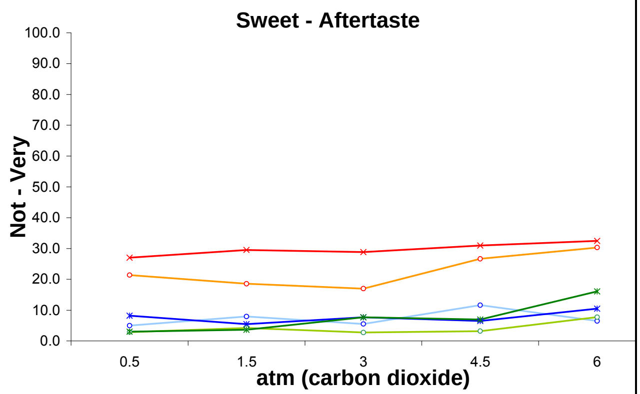
There was no significant difference found on the potato aftertaste attribute.



Second assessment



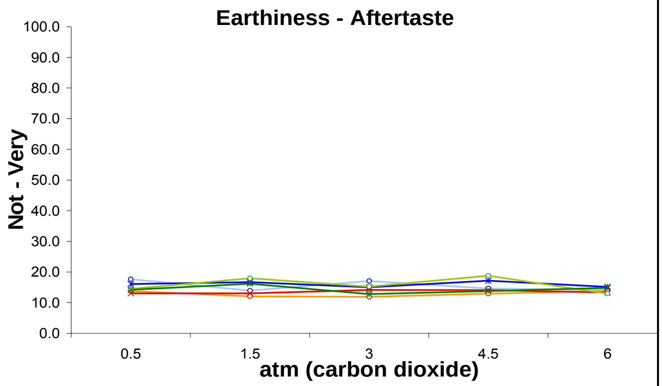
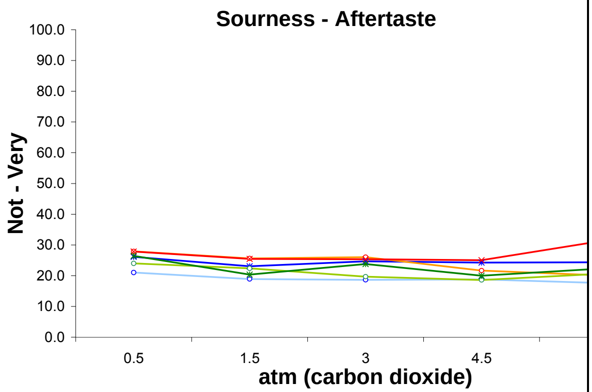
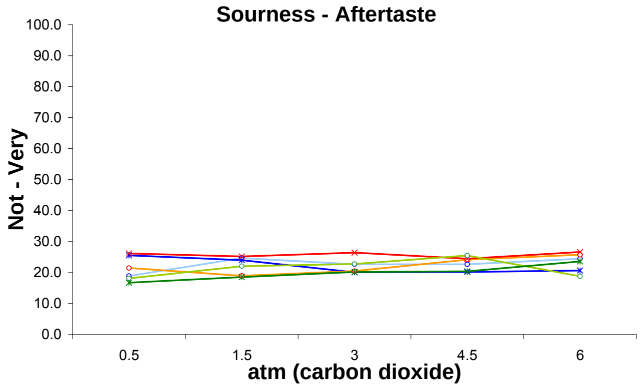
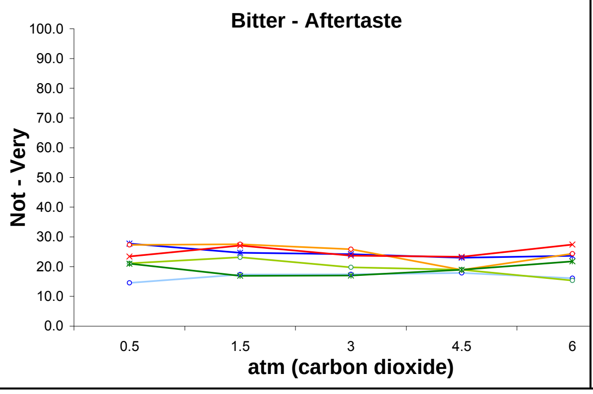




Key:

FIGURE A10 - MEAN SCORES FOR AFTERTASTE ATTRIBUTES (1)

Aftertaste - Significant Differing Attributes

First assessment	Second assessment
There was no significant difference found on the earthy aftertaste attribute.	
	
	There was no significant difference found on the bitter aftertaste attribute.

Key:

- Estima - Untreated
- Estima - Ethylene
- Marfona - Untreated
- Marfona - Ethylene
- Maris Piper - Untreated
- Maris Piper - Ethylene

FIGURE A11 - MEAN SCORES FOR AFTERTASTE ATTRIBUTES (2)

9.1.8.5.7. Afterfeel

Three attributes were assessed in the afterfeel category (Table 4 and 5). In both assessment 1 and 2 the astringent and mouthcoating attributes were significant.

9.1.8.5.8. Astringent

In assessment 1, within the Estima variety, the untreated potatoes were more astringent than the sprout suppressed potatoes stored at the same atmospheric conditions. This is similar for the Estima variety at assessment 2.

9.1.8.5.9. Mouthcoating

The untreated Maris Piper potatoes in assessment 1 were all significantly more mouthcoating than the correspondingly stored treated potatoes.
Furthermore, the Marfona potatoes were all significantly less mouthcoating that the Maris Piper potatoes in both assessment 1 and 2.

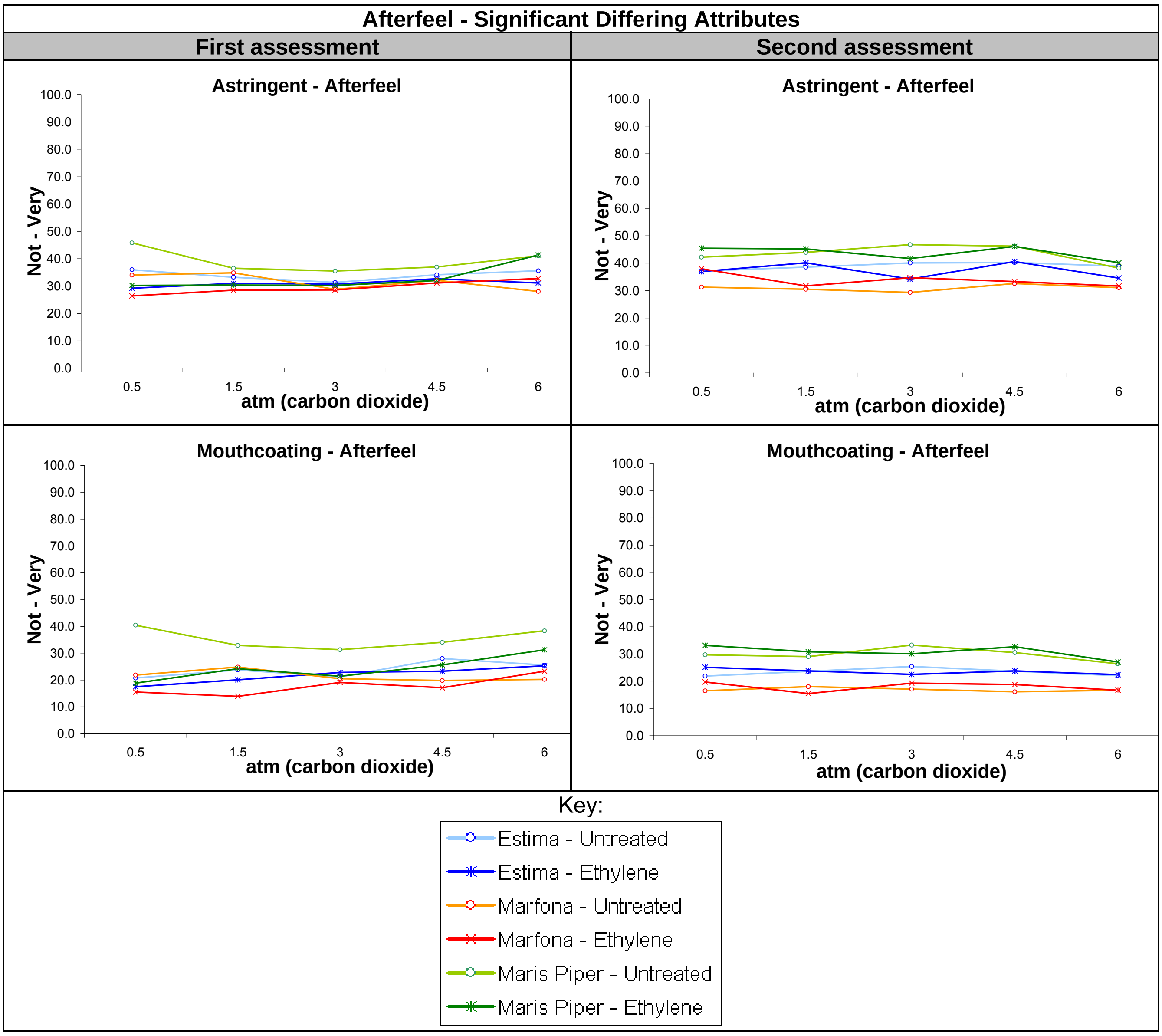


FIGURE A12 - MEAN SCORES FOR AFTERFEEL ATTRIBUTES

9.1.9. Principal Component Analysis

Principal Component Analysis (PCA) is a multivariate statistical technique, which can be applied to data sets comprising more than four samples to map perceptual relationships between those samples. PCA is used to reduce the dimensionality of complex data sets in such a way that the main information on the perceived relationships is contained in a limited number of two-dimensional plots. In these plots, closely positioned samples are perceived as very similar in the dimensions plotted, whereas samples positioned well apart are perceived as very different. The reasons for the sample positioning are interpreted using the original sensory attributes, which are plotted as vectors radiating from the origin. Samples positioned close to an attribute vector are strongly loaded on that attribute.

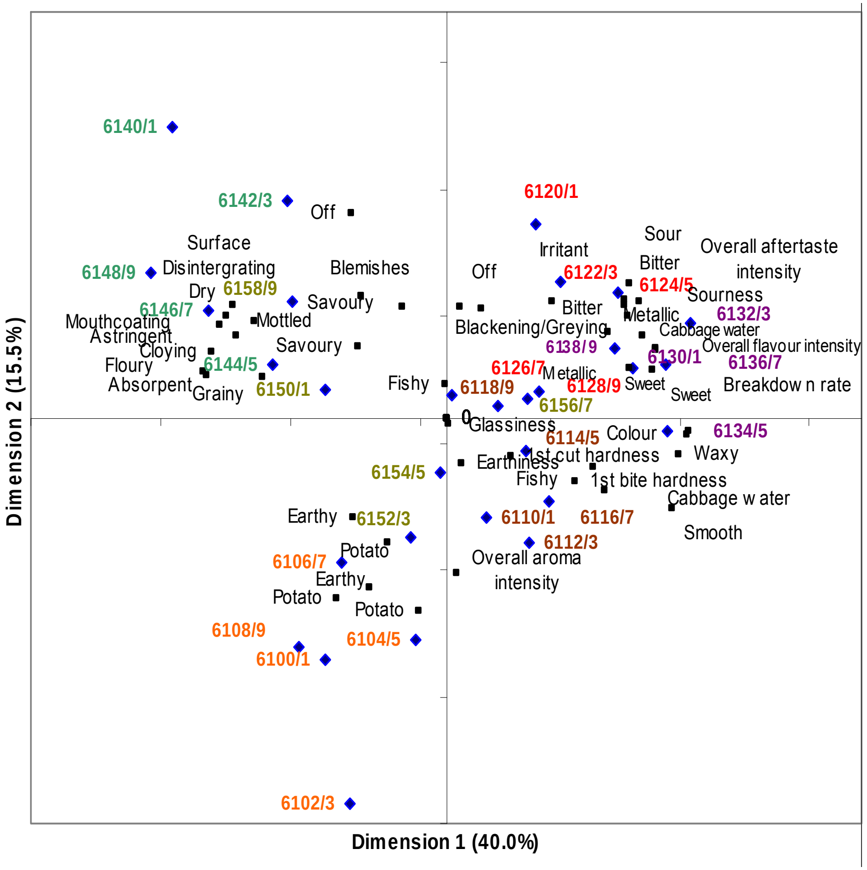
In assessment 1 the PCA gave a two-dimensional solution, with 40.0% of the variability in the data explained by PC1, 15.5% explained by PC2. Figure 13 shows the PCA plots for all samples and all attributes; Figure 14 shows the PCA plot for all samples and just the significant attributes where the two-dimensional solution explains 64.8% of the data.

In assessment 1 the Maris Piper untreated potatoes are located closely together in the upper left hand of the plot, closely associated with the surface disintegration and floury characters. Meanwhile the treated Maris Piper potatoes are located away from the untreated and more closely to the hardness on first bite and first cut attributes.

The untreated Estima potatoes are located on the lower left hand quadrant of the plot and are located near the potato and earthy characteristics. The treated Estima potatoes are all grouped very tightly together on the right and are more associated with the cabbage water and hardness attributes.

The untreated Marfona potatoes are found together on the right hand side, close to the treated Marfona potatoes. The treated Marfona potatoes are particularly strongly associated to the sweet attribute, cabbage water and overall flavour intensity attributes.

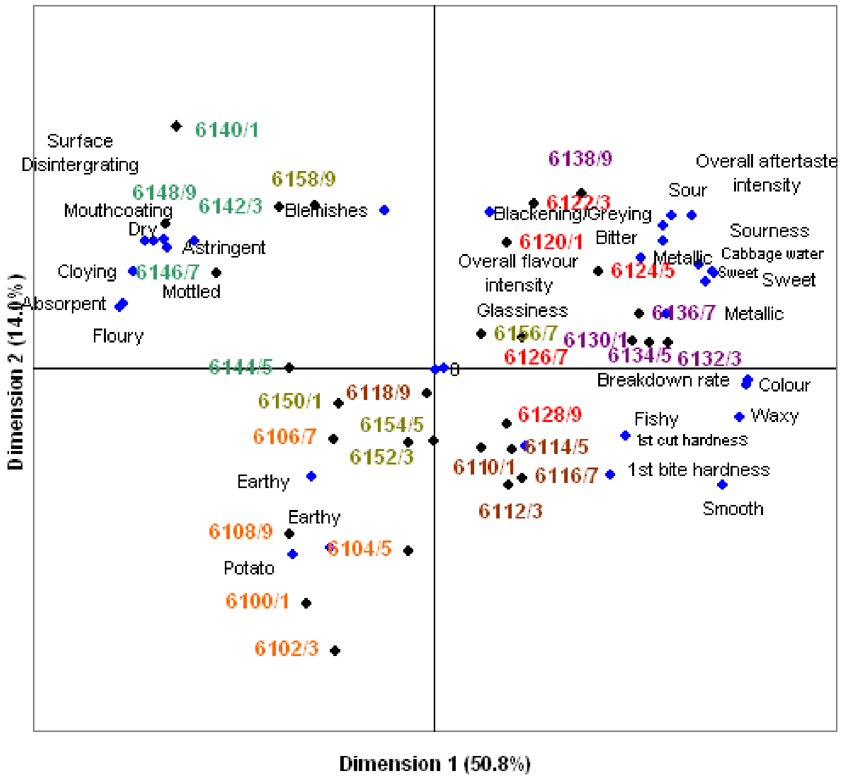
The placement of samples is similar when plotting just the significant attributes (Fig 14).



Key:

Sample Code	Sample Details		
Assessment 1	**Variety**	**Untreated/Ethylene**	**Atm CO_2**
6100/01	Estima	Untreated	0.5
6102/03	Estima	Untreated	1.5
6104/05	Estima	Untreated	3
6106/07	Estima	Untreated	4.5
6108/09	Estima	Untreated	6
6116/17	Estima	Ethylene	0.5
6112/13	Estima	Ethylene	1.5
6114/15	Estima	Ethylene	3
6110/11	Estima	Ethylene	4.5
6118/19	Estima	Ethylene	6
6120/21	Marfona	Untreated	0.5
6122/23	Marfona	Untreated	1.5
6124/25	Marfona	Untreated	3
6126/27	Marfona	Untreated	4.5
6128/29	Marfona	Untreated	6
6136/37	Marfona	Ethylene	0.5
6132/33	Marfona	Ethylene	1.5
6134/35	Marfona	Ethylene	3
6130/31	Marfona	Ethylene	4.5
6138/39	Marfona	Ethylene	6
6140/41	Maris Piper	Untreated	0.5
6142/43	Maris Piper	Untreated	1.5
6144/45	Maris Piper	Untreated	3
6146/47	Maris Piper	Untreated	4.5
6148/49	Maris Piper	Untreated	6
6156/57	Maris Piper	Ethylene	0.5
6152/53	Maris Piper	Ethylene	1.5
6154/55	Maris Piper	Ethylene	3
6150/51	Maris Piper	Ethylene	4.5
6158/59	Maris Piper	Ethylene	6

FIGURE A13 - PCA PLOT – ALL POTATO SAMPLES, ALL ATTRIBUTES – ASSESSMENT 1



Sample Code	Sample Details		
Assessment 1	Variety	Untreated/Ethylene	Atm CO_2
6100/01	Estima	Untreated	0.5
6102/03	Estima	Untreated	1.5
6104/05	Estima	Untreated	3
6106/07	Estima	Untreated	4.5
6108/09	Estima	Untreated	6
6116/17	Estima	Ethylene	0.5
6112/13	Estima	Ethylene	1.5
6114/15	Estima	Ethylene	3
6110/11	Estima	Ethylene	4.5
6118/19	Estima	Ethylene	6
6120/21	Marfona	Untreated	0.5
6122/23	Marfona	Untreated	1.5
6124/25	Marfona	Untreated	3
6126/27	Marfona	Untreated	4.5
6128/29	Marfona	Untreated	6
6136/37	Marfona	Ethylene	0.5
6132/33	Marfona	Ethylene	1.5
6134/35	Marfona	Ethylene	3
6130/31	Marfona	Ethylene	4.5
6138/39	Marfona	Ethylene	6
6140/41	Maris Piper	Untreated	0.5
6142/43	Maris Piper	Untreated	1.5
6144/45	Maris Piper	Untreated	3
6146/47	Maris Piper	Untreated	4.5
6148/49	Maris Piper	Untreated	6
6156/57	Maris Piper	Ethylene	0.5
6152/53	Maris Piper	Ethylene	1.5
6154/55	Maris Piper	Ethylene	3
6150/51	Maris Piper	Ethylene	4.5
6158/59	Maris Piper	Ethylene	6

FIGURE A14 - PCA PLOT - ALL THE POTATO SAMPLES, SIGNIFICANT ATTRIBUTES – ASSESSMENT 1

Key:

In assessment 2 the Principal Component Analysis (PCA) of all samples and all attributes gave a two-dimensional solution, with 50.3% of the variability in the data explained by PC1, 11.7% explained by PC2. Figure 15 shows the PCA plots for all samples and all attributes; Figure 16 shows the PCA plot for all samples and just the significant attributes where the three-dimensional solution explains 79.7% of the data.

In comparison to assessment 1 there is less separation of the treated from untreated potatoes within each variety.

The Maris Piper untreated and treated potatoes are located closely together on the left of the plot.

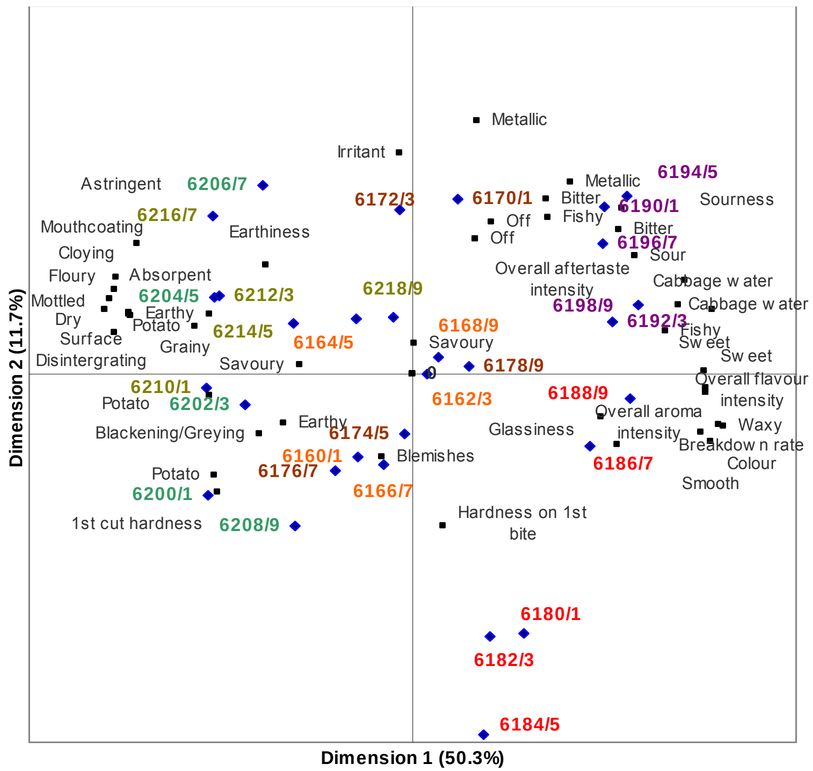
The Estima potatoes are positioned centrally on the plot indicating that its characteristics are between the more differentiating varieties of Maris Piper and Marfona.

The Marfona potatoes were positioned on the right hand side of the plot where the untreated Marfona potatoes were associated with hardness on first bite. The treated potatoes were associated with sweetness, cabbage water and sourness.

When looking at Figure 16 it is seen that the positions of the respective potatoes and corresponding attributes have moved, displaying a mirror image of figure 15.

The treated Marfona potatoes were associated with the cabbage, sweet, overall flavour intensity and sour characteristics. Marfona potatoes 6182/1, 6182/3 and 6184/5 were positioned closely to the hardness of 1st bite attribute.

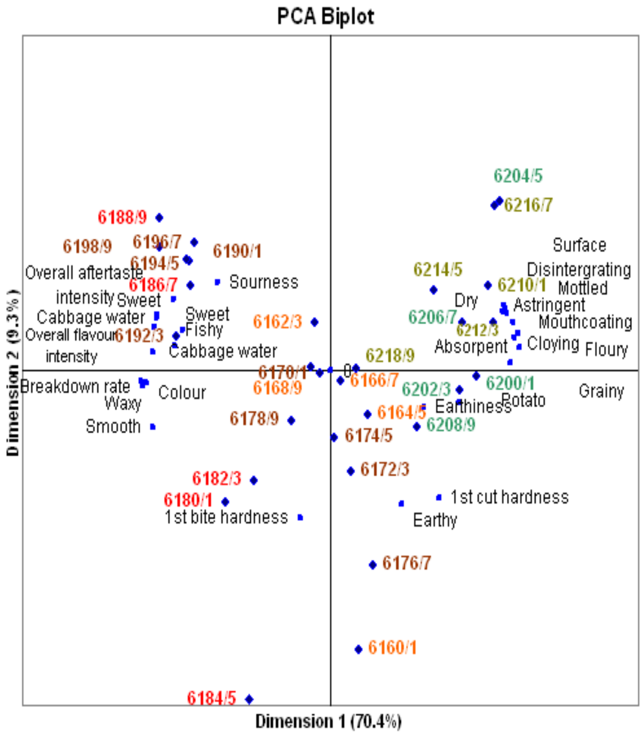
Most of the untreated Maris Piper potatoes were found near the earthy, potato, dry and absorbent attributes. All of the Maris Piper potatoes were strongly associated with the mottled, surface disintegrating, astringent, mouthcoating, cloying and floury attributes.



Key:

Sample Code	Sample Details		
Assessment 2	**Variety**	**Untreated/Ethylene**	**Atm CO_2**
6160/61	Estima	Untreated	0.5
6162/63	Estima	Untreated	1.5
6164/65	Estima	Untreated	3
6166/67	Estima	Untreated	4.5
6168/69	Estima	Untreated	6
6170/71	Estima	Ethylene	0.5
6172/73	Estima	Ethylene	1.5
6174/75	Estima	Ethylene	3
6176/77	Estima	Ethylene	4.5
6178/79	Estima	Ethylene	6
6180/81	Marfona	Untreated	0.5
6182/83	Marfona	Untreated	1.5
6184/85	Marfona	Untreated	3
6186/87	Marfona	Untreated	4.5
6188/89	Marfona	Untreated	6
6190/91	Marfona	Ethylene	0.5
6192/93	Marfona	Ethylene	1.5
6194/95	Marfona	Ethylene	3
6196/97	Marfona	Ethylene	4.5
6198/99	Marfona	Ethylene	6
6200/01	Maris Piper	Untreated	0.5
6202/03	Maris Piper	Untreated	1.5
6204/05	Maris Piper	Untreated	3
6206/07	Maris Piper	Untreated	4.5
6208/09	Maris Piper	Untreated	6
6210/11	Maris Piper	Ethylene	0.5
6212/13	Maris Piper	Ethylene	1.5
6214/15	Maris Piper	Ethylene	3
6216/17	Maris Piper	Ethylene	4.5
6218/19	Maris Piper	Ethylene	6

FIGURE A15 - PCA PLOT - ALL POTATO SAMPLES, ALL ATTRIBUTES – ASSESSMENT 2



Key:

Sample Code		Sample Details	
Assessment 2	**Variety**	**Untreated/Ethylene**	**Atm CO_2**
6160/61	Estima	Untreated	0.5
6162/63	Estima	Untreated	1.5
6164/65	Estima	Untreated	3
6166/67	Estima	Untreated	4.5
6168/69	Estima	Untreated	6
6170/71	Estima	Ethylene	0.5
6172/73	Estima	Ethylene	1.5
6174/75	Estima	Ethylene	3
6176/71	Estima	Ethylene	4.5
6178/79	Estima	Ethylene	6
6180/81	Marfona	Untreated	0.5
6182/83	Marfona	Untreated	1.5
6184/85	Marfona	Untreated	3
6186/87	Marfona	Untreated	4.5
6188/89	Marfona	Untreated	6
6190/91	Marfona	Ethylene	0.5
6192/93	Marfona	Ethylene	1.5
6194/95	Marfona	Ethylene	3
6190/91	Marfona	Ethylene	4.5
6198/99	Marfona	Ethylene	6
6200/01	Maris Piper	Untreated	0.5
6202/03	Maris Piper	Untreated	1.5
6204/05	Maris Piper	Untreated	3
6206/07	Maris Piper	Untreated	4.5
6208/09	Maris Piper	Untreated	6
6210/81	Maris Piper	Ethylene	0.5
6212/13	Maris Piper	Ethylene	1.5
6214/15	Maris Piper	Ethylene	3
6216/17	Maris Piper	Ethylene	4.5
6218/19	Maris Piper	Ethylene	6

FIGURE A16 - PCA PLOT – ALL POTATO SAMPLES, SIGNIFICANT ATTRIBUTES – ASSESSMENT 2

9.1.10. Conclusions

The main differences identified were between potato varieties, with the Marfona and Maris Piper being most distinct.

9.1.10.1. Estima

The Estima potatoes were positioned, for the majority of the attributes, between the Marfona and Maris Piper potatoes.
The variety was described as potato, earthy and cabbage water in aroma and flavour with a slight sour and bitter flavour and some metallic flavour notes. The potatoes had an average darkness of colour, a smooth appearance, slightly dry with only very few (least of sample set) blemishes and blackening/greying.
The texture of the Estima potato was described as absorbent, cloying and quite floury with a moderate breakdown rate, slightly waxy and grainy. It was also relatively soft on first cut and bite.

9.1.10.2. Marfona

The Marfona potatoes were identified as potato, earthy and cabbage water in flavour and aroma, however, they were the weakest in the sample set for potato and earthy aromas. The potatoes were relatively sweet and sour, they had a slight bitter taste, some metallic notes and the strongest overall flavour intensity, which all persisted into the aftertaste. On appearance, the Marfona potato was identified as having the darkest colour, a slight dryness, with a slight amount of blemishes and a darkening/greying. This variety had the smoothest surface in the sample set, tying in well with the waxy texture, less flouriness and faster breakdown. Although a moderate degree of absorbency was identified, this potato was the least absorbent in the sample set.

9.1.10.3. Maris Piper

The Maris Piper potatoes had a potato, earthy and cabbage water character, the latter attribute being the weakest of the sample set. A slight sour and bitter taste and metallic notes were identified on both flavour and aftertaste. Maris Piper potatoes were the lightest coloured potatoes, with the least smooth appearance and most disintegrating and mottled surface. The appearance looked slightly dry and the potatoes had a small amount of blemishes and blackening/greying present. The in-mouth texture of the potatoes was quite different to the other two variants; being the most floury, cloying, grainy and absorbent, and with the slowest breakdown rate.

9.1.10.4. Treated versus Untreated

Across the varieties evaluated, the treated potato was found to be waxier, stronger in overall flavour and aftertaste, sweeter, stronger in cabbage water flavour and very slightly fishier than the corresponding untreated potato in both assessment 1 and 2.
This held true in assessment 1, however, more differences were highlighted between the treated and untreated potatoes. Besides the above mentioned attributes the treated potatoes were also identified as darker in colour, smoother in appearance, less

absorbent, floury and cloying, faster in breakdown rate, more sour, slightly harder to cut and bite and giving less mouth coating after swallowing the potato.

9.1.10.5. Level of Carbon Dioxide

The level of carbon dioxide seemed to have a lesser influence on the differentiation between the potatoes. However, some indications have been highlighted; possibly the carbon dioxide darkened the potatoes, gave a smoother appearance at the highest level (assessment 2 only), and gave a waxier texture to the potatoes stored at the higher levels.

9.1.11. Varimax PCA

Varimax PCA on the mean scores for all 44 attributes and 60 potato samples was carried out. Four dimensions explaining 72.9% of the total variation among the sensory scores are shown.

The first dimension has quite a mixture of different attributes, mouthfeel and appearance for example, that would be thought directly related. Likewise, dimension two seems to be a mixture of aroma and bitter/sourness attributes.

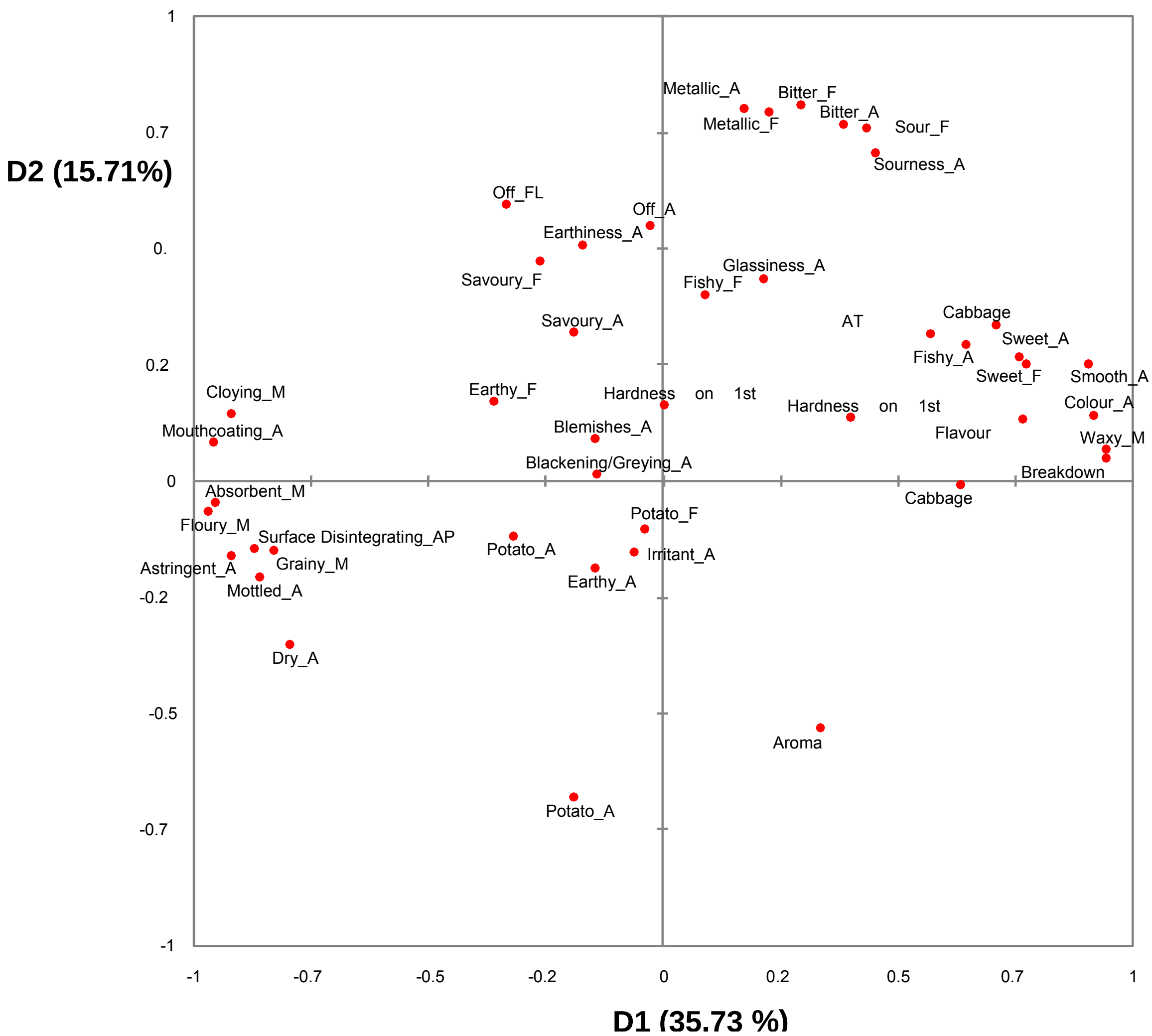


FIGURE A17. VARIABLES (AXES D1 AND D2: 51.43%) AFTER VARIMAX ROTATION %

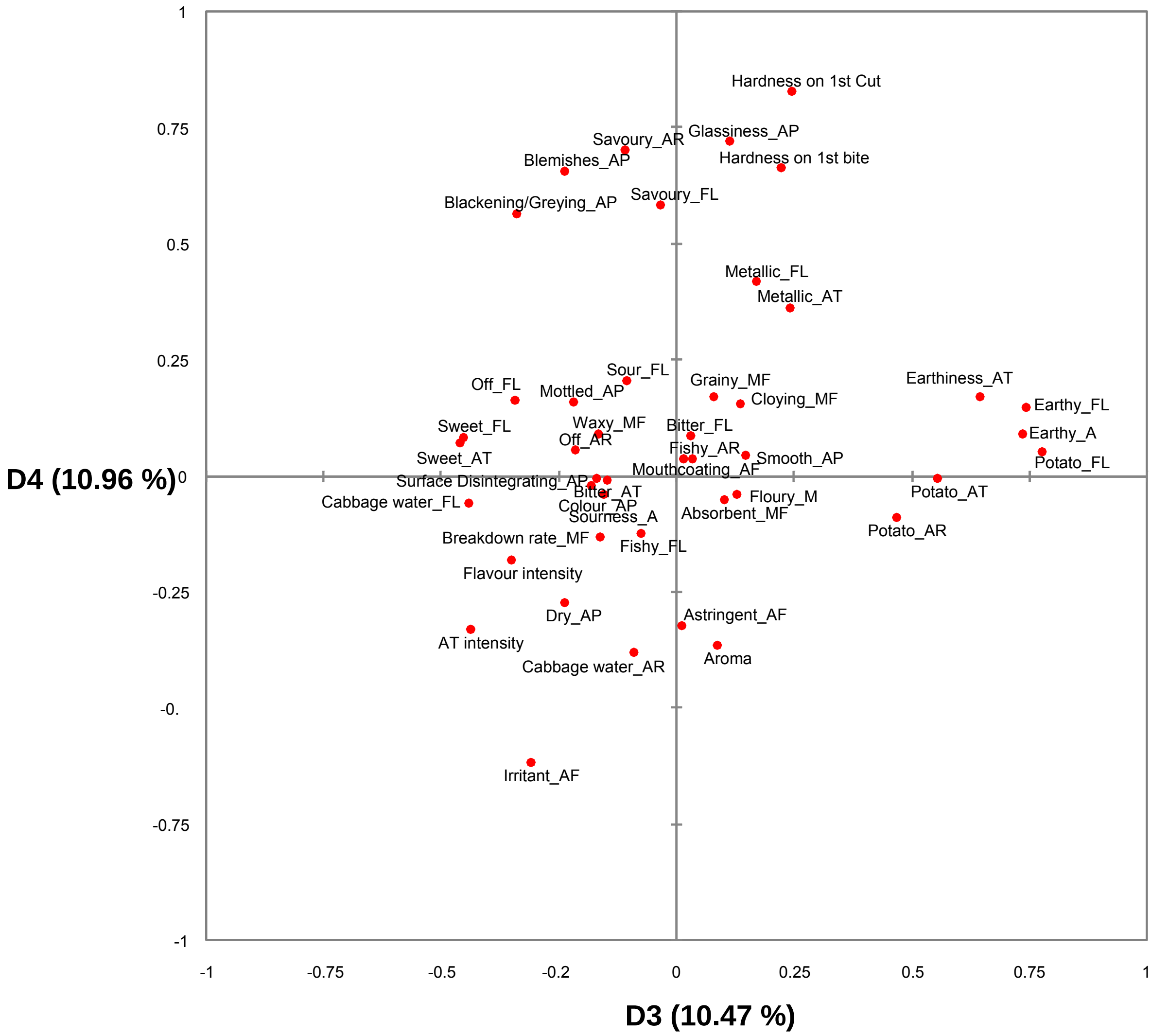
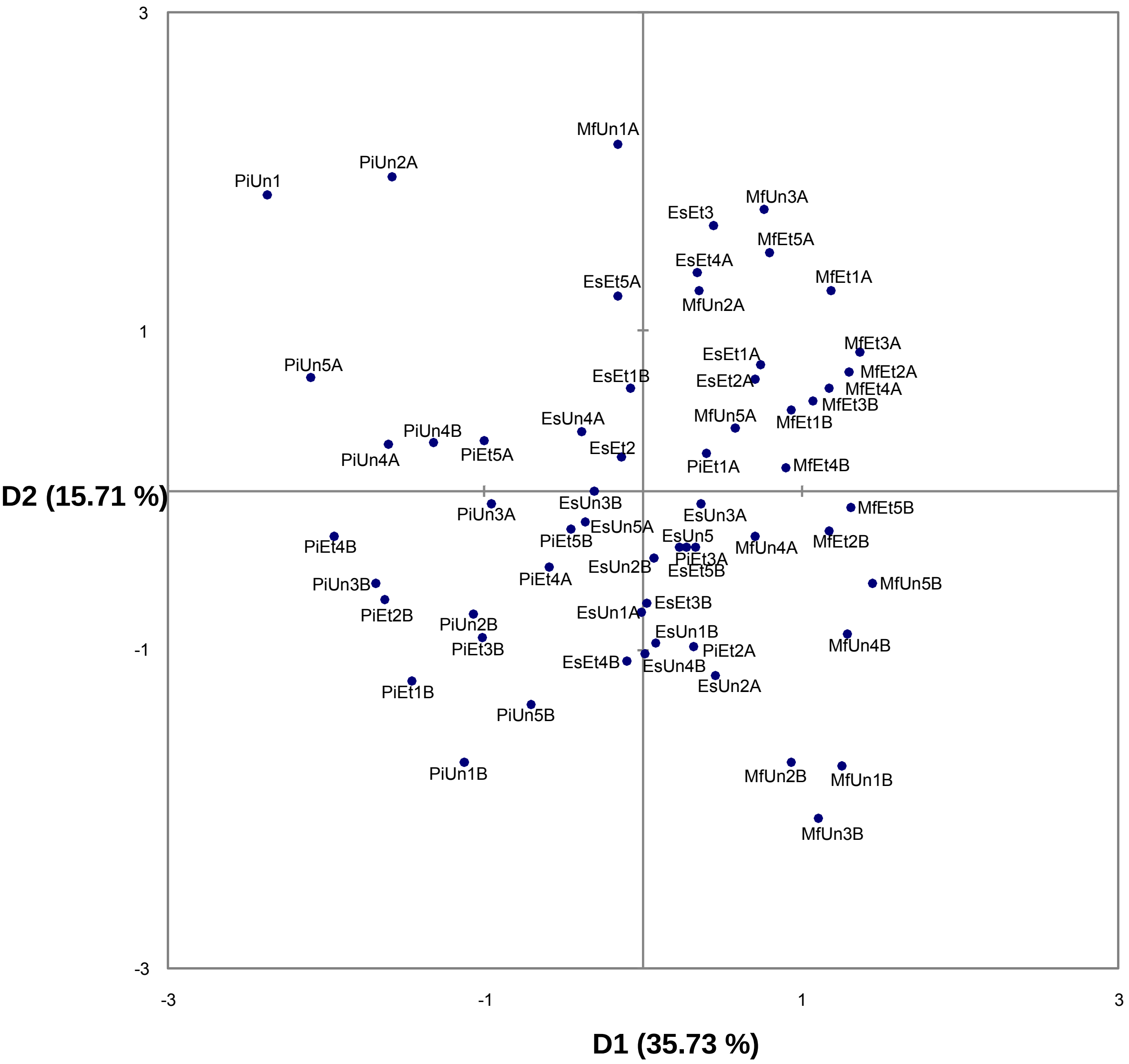


FIGURE A18. VARIABLES (AXES D3 AND D4: 21.44 %)AFTER VARIMAX ROTATION

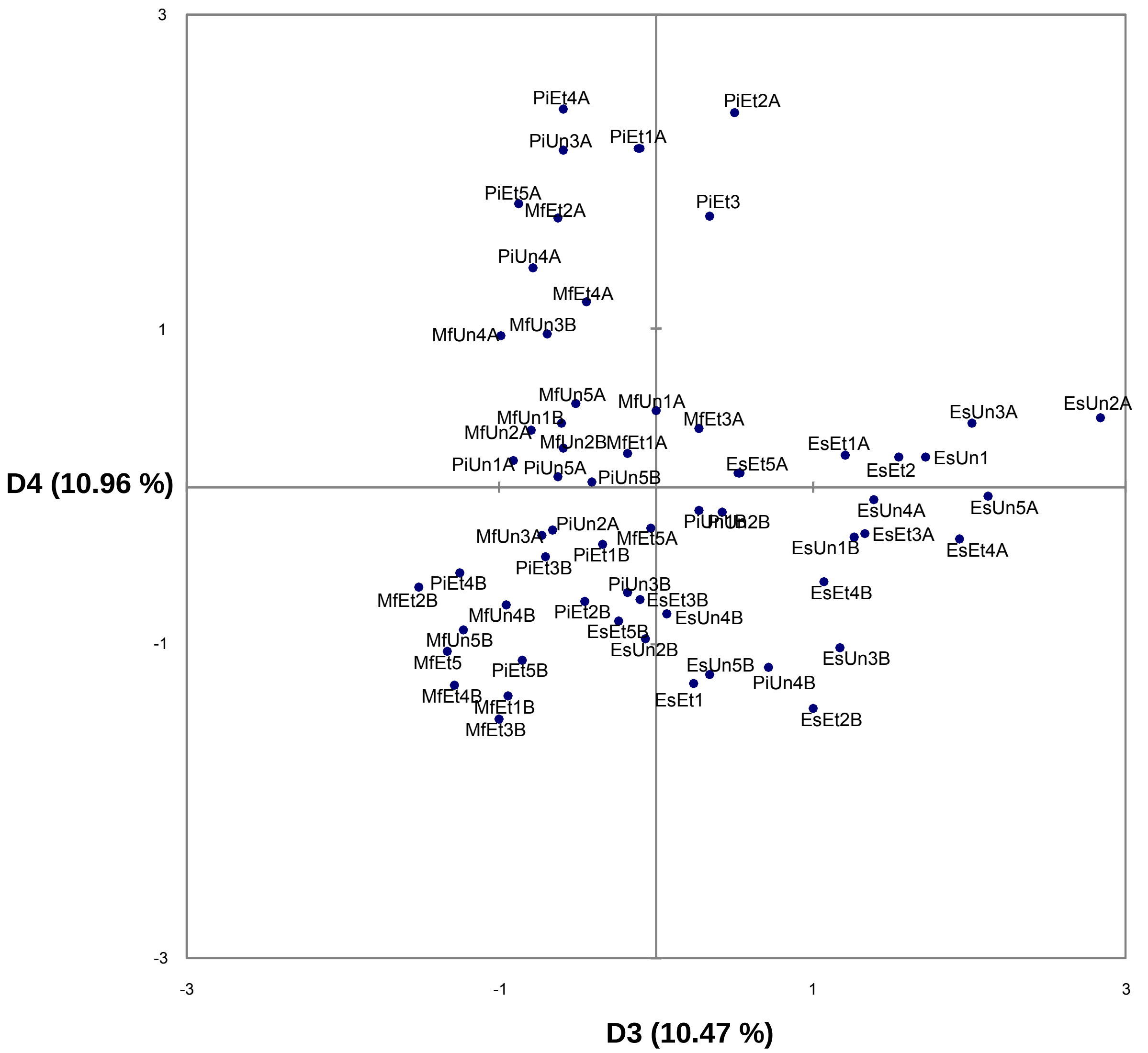


Key:

Pi=Maris Piper
Es=Estima
Mf=Marfona
Un=Untreated
Et=Ethylene

1=0.5 CO_2
2=1.5 CO_2
3=3.0 CO_2
4=4.5 CO_2
5=6.0 CO_2
A=January
B=June

FIGURE A19. OBSERVATIONS (AXES D1 AND D2: 51.43 %) AFTER VARIMAX ROTATION



Key:

	1=0.5 CO_2
	2=1.5 CO_2
Pi=Maris Piper	3=3.0 CO_2
Es=Estima	4=4.5 CO_2
Mf=Marfona	5=6.0 CO_2
Un=Untreated	A=January
Et=Ethylene	B=June

FIGURE A20. OBSERVATIONS (AXES D3 AND D4: 21.44 %) AFTER VARIMAX ROTATION

9.1.12. Clustering the Variables

VARCLUS was used for the clustering of the variables using 60 potato samples and 4 attributes. Eight clusters were identified. Table A6 below contains the scoring coefficients; where a non-zero coefficient tells to which cluster an attributes contributes. This sign of the coefficients indicates whether contribution is positive or negative.

Tentative assignments of the underlying sensory dimensions associated with each cluster are made. Cluster one is the most complex, but does seem to have a fairly consistent textural theme, the other clusters have fairly obvious interpretations.

Assignments	Crumbly/ Dry	Sour/Bitter /Metallic	Potato/ Earthy	Hard/ Savoury	Sweet/ Intense	Off Notes	Bad Appearance	Aromatic
Attributes	Clus1	Clus2	Clus3	Clus4	Clus5	Clus6	Clus7	Clus8
Aroma intensity	0	0	0	0	0	0	0	0.55978
Potato_AR	0	0	0	0	0	0	0	0.55978
Fishy_AR	-0.059598	0	0	0	0	0	0	0
Savoury_AR	0	0	0	0.22274	0	0	0	0
Earthy_AR	0	0	0.25487	0	0	0	0	0
Cabbage water_AR	0	0	0	0	0.14772	0	0	0
Off_AR	0	0	0	0	0	0.47882	0	0
Colour_AP	-0.080528	0	0	0	0	0	0	0
Smooth_AP	-0.082515	0	0	0	0	0	0	0
Dry_AP	0.073979	0	0	0	0	0	0	0
Blemishes_AP	0	0	0	0	0	0	0.55756	0
Glassiness_AP	0	0	0	0.22865	0	0	0	0
Blackening/ Greying_AP	0	0	0	0	0	0	0.55756	0
Mottled_AP	0.077809	0	0	0	0	0	0	0
Surface Disintegrating_AP	0.082819	0	0	0	0	0	0	0
Hardness on 1st Cut	0	0	0	0.22985	0	0	0	0
Hardness on 1st bite	0	0	0	0.19429	0	0	0	0
Absorbent_MF	0.083433	0	0	0	0	0	0	0
Waxy_MF	-0.081812	0	0	0	0	0	0	0
Floury_MF	0.084924	0	0	0	0	0	0	0
Cloying_MF	0.078085	0	0	0	0	0	0	0
Grainy_MF	0.074751	0	0	0	0	0	0	0
Breakdown rate_MF	-0.08239	0	0	0	0	0	0	0
Flavour intensity	0	0	0	0	0.19946	0	0	0
Potato_FL	0	0	0.25256	0	0	0	0	0
Sweet_FL	0	0	0	0	0.19747	0	0	0
Fishy_FL	0	0	0	0	0	0.37399	0	0
Savoury_FL	0	0	0	0.21369	0	0	0	0
Earthy_FL	0	0	0.28289	0	0	0	0	0
Sour_FL	0	0.19781	0	0	0	0	0	0
Bitter_FL	0	0.19137	0	0	0	0	0	0
Metallic_FL	0	0.19168	0	0	0	0	0	0
Cabbage water_FL	0	0	0	0	0.19473	0	0	0
Off_FL	0	0	0	0	0	0.41743	0	0
AT intensity	0	0	0	0	0.18516	0	0	0
Potato_AT	0	0	0.23916	0	0	0	0	0
Sweet_AT	0	0	0	0	0.19915	0	0	0
Metallic_AT	0	0.18609	0	0	0	0	0	0
Earthiness_AT	0	0	0.24016	0	0	0	0	0
Sourness_AT	0	0.1836	0	0	0	0	0	0
Bitter_AT	0	0.18355	0	0	0	0	0	0
Astringent_AF	0.078689	0	0	0	0	0	0	0
Mouthcoating_AF	0.082187	0	0	0	0	0	0	0
Irritant_AF	0	0	0	-0.19325	0	0	0	0

These are Standardized Scoring Coefficients from running SAS PROC VARCLUS on the combined sensory mean scores from both the January and June parts of the experiment. Both sets of sensory panels means are calculated using the common set of 10 assessors.

The non-zero values are the multipliers that are used to construct the scores for each cluster of sensory attributes. Scores are calculated on the normalised sensory attributes.

TABLE A6. SCORING COEFFICIENTS OF THE CLUSTERED VARIABLES

9.1.13. GLM Modelling

Using the eight cluster summary of the sensory data, the scores were analysed using an ANOVA model with the main effects and a selection of relevant two and three factor interactions.
Where there is a significant term in the model, this is highlighted with a red p-value in the right most column of the table. Line charts are displayed of all significant two way interactions.

9.1.13.1. Means

	Estima	Marfona	Maris Piper	LSD	Prob
Crumbly/Dry	-0.06	-0.46	0.52	0.06	<.0001
Sour/Bitter/Metallic	-0.02	0.11	-0.08	0.09	<.0001
Potato/Earthy	0.13	-0.15	0.02	0.09	<.0001
Hard/Savoury	-0.04	-0.01	0.05	0.06	0.0107
Sweet/Intense	-0.18	0.45	-0.26	0.07	<.0001
Off Notes	-0.05	0.02	0.04	0.10	0.1504
Bad Appearance	-0.22	0.04	0.19	0.10	<.0001
Aromatic	0.06	-0.06	0.01	0.13	0.1988

TABLE A7. MEANS FOR VARIETY

	Untreated	Ethylene	LSD	Prob
Crumbly/Dry	0.09	-0.09	0.05	<.0001
Sour/Bitter/Metallic	-0.05	0.05	0.07	0.0033
Potato/Earthy	0.01	-0.01	0.07	0.7778
Hard/Savoury	-0.02	0.02	0.05	0.1234
Sweet/Intense	-0.11	0.11	0.06	<.0001
Off Notes	-0.03	0.03	0.08	0.1465
Bad Appearance	-0.03	0.03	0.08	0.2056
Aromatic	0.00	0.00	0.10	0.9353

TABLE A8. MEANS FOR ETHYLENE

	0.5	1.5	3	4.5	6	LSD	Prob
Crumbly/Dry	0.03	-0.02	-0.05	0.05	-0.01	0.0751	0.0552
Sour/Bitter/Metallic	0.03	0.01	0.02	-0.04	-0.02	0.1101	0.7100
Potato/Earthy	0.03	0.01	-0.01	0.01	-0.04	0.1116	0.8149
Hard/Savoury	0.00	0.03	0.05	-0.02	-0.06	0.0815	0.0672
Sweet/Intense	-0.07	-0.03	0.01	0.02	0.07	0.0909	0.0269
Off Notes	0.04	-0.05	-0.06	0.05	0.02	0.1249	0.2898
Bad Appearance	0.08	0.02	-0.08	0.01	-0.03	0.1314	0.2172
Aromatic	0.04	0.01	0.00	-0.02	-0.03	0.165	0.9402

TABLE A9. MEANS FOR CO_2

	January	June	LSD	Prob
Crumbly/Dry	-0.06	0.06	0.05	<.0001
Sour/Bitter/Metallic	0.13	-0.13	0.07	<.0001
Potato/Earthy	0.05	-0.05	0.07	0.0064
Hard/Savoury	0.23	-0.23	0.05	<.0001
Sweet/Intense	0.02	-0.02	0.06	0.2668
Off Notes	0.06	-0.06	0.08	0.0016
Bad Appearance	0.09	-0.09	0.08	<.0001
Aromatic	-0.11	0.11	0.10	<.0001

TABLE A10. MEANS FOR TIME

9.1.13.2. Time- variety interaction

	January			June					
	Estim a	Marfona	Maris Piper	Estima	Marfona	Maris Piper	LSD	Prob	Half LSD
Crumbly/Dry	-0.11	-0.44	0.38	-0.02	-0.47	0.66	0.08	<.0001	0.04115
Sour/Bitter/Metallic	0.08	0.28	0.03	-0.13	-0.06	-0.20	0.12	0.2997	0.0603
Potato/Earthy	0.21	-0.09	0.03	0.06	-0.21	0.01	0.12	0.2872	0.06115
Hard/Savoury	0.16	0.19	0.35	-0.25	-0.21	-0.25	0.09	0.0032	0.04465
Sweet/Intense	-0.18	0.41	-0.18	-0.18	0.48	-0.35	0.10	0.0057	0.0498
Off Notes	-0.05	0.07	0.17	-0.06	-0.04	-0.10	0.14	0.0295	0.0684
Bad Appearance	-0.28	0.17	0.38	-0.16	-0.09	-0.01	0.14	<.0001	0.07195
Aromatic	0.01	-0.24	-0.09	0.10	0.12	0.10	0.18	0.1041	0.0904

TABLE A11. TIME- VARIETY INTERACTION SCORE SUMMARY

		January	June
Crumbly/Dry	**Estima**	-0.1102	-0.0176
	Marfona	-0.4372	-0.4742
	Maris Piper	0.3798	0.6595
Hard/Savoury	**Estima**	0.1615	-0.2488
	Marfona	0.1922	-0.2096
	Maris Piper	0.3502	-0.2454
Sweet/Intense	**Estima**	-0.1799	-0.182
	Marfona	0.4132	0.4783
	Maris Piper	-0.1846	-0.3451
	Estima	-0.0514	-0.0569
Off Notes	**Marfona**	0.0723	-0.0387
	Maris Piper	0.1704	-0.0957
Bad Appearance	**Estima**	-0.2831	-0.1622
	Marfona	0.1664	-0.0924
	Maris Piper	0.3835	-0.0123

TABLE A12. TIME- VARIETY INTERACTION SCORE SUMMARY(4DP)

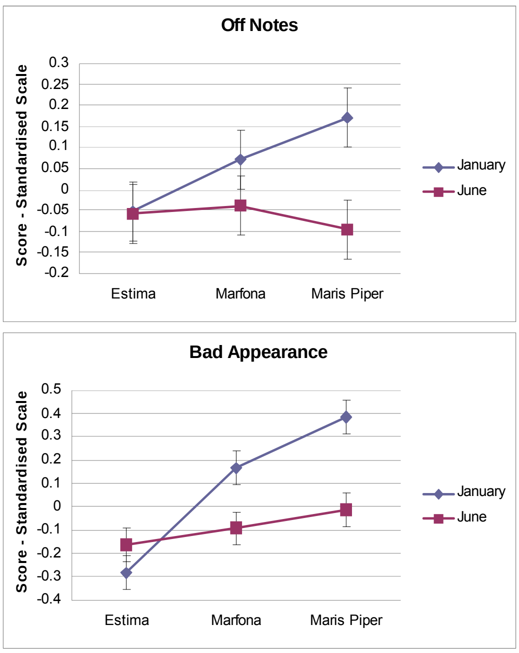


FIGURE A21. TIME- VARIETY INTERACTION: OFF NOTES AND BAD APPEARANCE

9.1.13.3. Time – Ethylene interaction

	January		June				
	Untreated	Ethylene	Untreated	Ethylene	LSD	Prob	
Crumbly/Dry	0.13	-0.25	0.05	0.06	0.07	<.0001	0.0336
Sour/Bitter/Metallic	0.06	0.20	-0.17	-0.09	0.10	0.4063	0.0492
Potato/Earthy	0.03	0.07	-0.02	-0.08	0.10	0.1150	0.0499
Hard/Savoury	0.16	0.31	-0.20	-0.27	0.07	<.0001	0.03645
Sweet/Intense	-0.13	0.16	-0.09	0.06	0.08	0.0217	0.04065
Off Notes	0.07	0.05	-0.13	0.00	0.11	0.0516	0.05585
Bad Appearance	0.01	0.17	-0.06	-0.12	0.12	0.0083	0.05875
Aromatic	-0.15	-0.07	0.14	0.07	0.15	0.1370	0.0738

TABLE A13. TIME- ETHYLENE INTERACTION SCORE SUMMARY

Crumbly/Dry

	January	June
Untreated	0.1332	0.0526
Ethylene	-0.245	0.0592

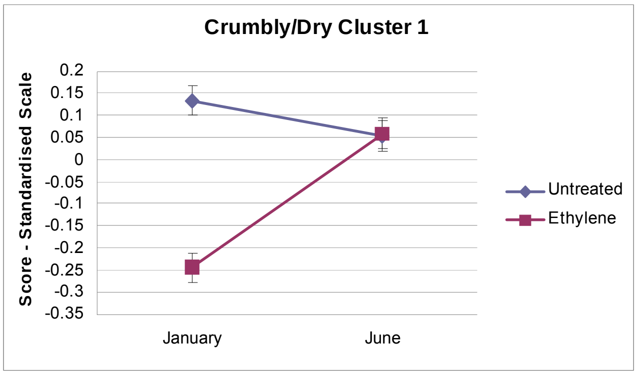


FIGURE A22. TIME- ETHYLENE INTERACTION SCORE: CRUMBLY/DRY

Hard/Savoury

	January	June
Untreated	0.1608	-0.2013
Ethylene	0.3084	-0.2679

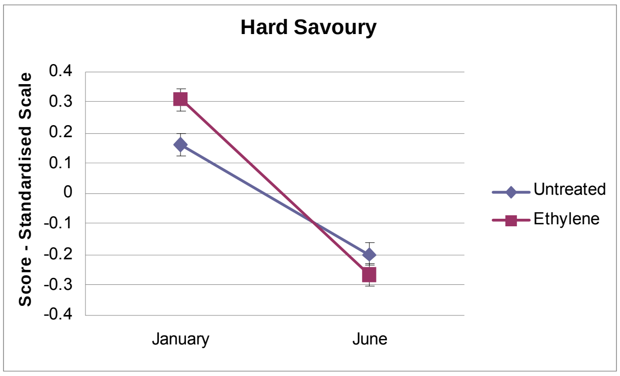


FIGURE A23. TIME- ETHYLENE INTERACTION SCORE: HARD/SAVOURY

Sweet/Intense

	January	June
Untreated	-0.1253	-0.0904
Ethylene	0.1578	0.0579

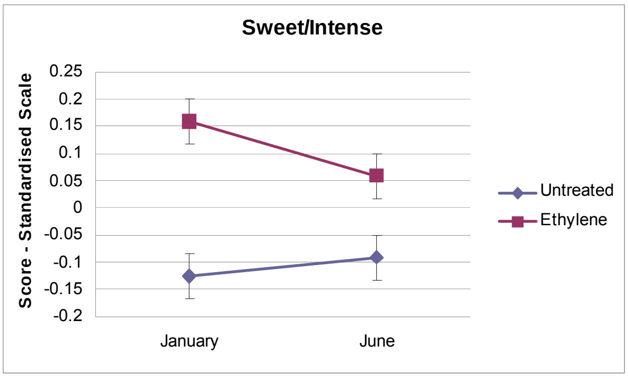


FIGURE A24. TIME- ETHYLENE INTERACTION SCORE: SWEET/INTENSE

9.1.13.4. Time - CO_2 interaction

	January					June						
	0.5	1.5	3	4.5	6	0.5	1.5	3	4.5	6	LSD	Prob
Crumbly/Dry	-0.03	-0.13	-0.22	-0.03	0.12	0.09	0.09	0.11	0.13	-0.14	0.11	<.0001
Sour/Bitter/Metallic	0.22	0.14	0.16	0.05	0.08	-0.16	-0.12	-0.12	-0.13	-0.12	0.16	0.4329
Potato/Earthy	0.05	0.06	0.05	0.03	0.05	0.00	-0.04	-0.06	-0.02	-0.12	0.16	0.8361
Hard/Savoury	0.22	0.29	0.30	0.23	0.13	-0.22	-0.24	-0.20	-0.27	-0.25	0.12	0.3513
Sweet/Intense	-0.06	0.02	0.10	0.03	0.00	-0.08	-0.08	-0.08	0.01	0.15	0.13	0.0076
Off Notes	0.09	0.02	0.05	0.12	0.04	-0.01	-0.12	-0.17	-0.02	0.00	0.18	0.7571
Bad Appearance	0.17	0.08	-0.05	0.12	0.12	-0.02	-0.04	-0.10	-0.10	-0.19	0.19	0.3870
Aromatic	-0.13	-0.07	-0.02	-0.18	-0.14	0.20	0.09	0.03	0.13	0.08	0.23	0.4807

TABLE A14. TIME- CO_2 INTERACTION SCORE SUMMARY

Crumbly/Dry

CO_2	January	June
0.5	-0.0322	0.085
1.5	-0.1277	0.0897
3	-0.2179	0.1098
4.5	-0.025	0.1308
6	0.1234	-0.1358

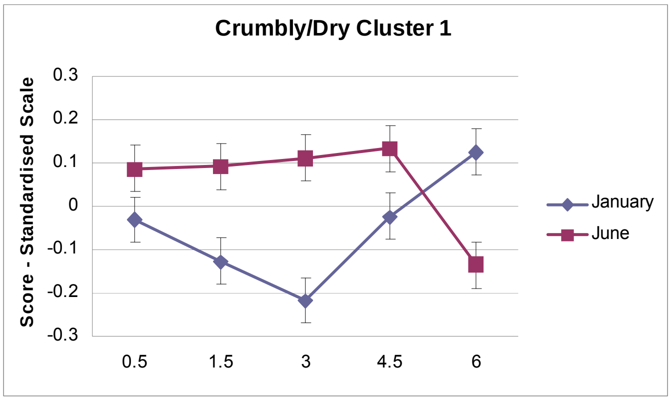


FIGURE A25. TIME- CO_2 INTERACTION SCORE: CRUMBLY/DRY

Sweet/Intense	CO_2	January	June
	0.5	-0.0623	-0.0806
	1.5	0.0172	-0.0774
	3	0.1001	-0.0818
	4.5	0.0283	0.0095
	6	-0.002	0.149

FIGURE A26. TIME- CO_2 INTERACTION SCORE: SWEET/INTENSE

9.1.13.5. Ethylene - CO2 interaction

There is one significant interaction for the crumbly/dry attribute cluster; it appears that at high CO_2 levels that treating with ethylene makes almost no difference, however, at lower CO_2 levels, the effect of treating with ethylene makes the samples significantly less crumbly/dry.

	Untreated					**Ethylene**						
	0.5	1.5	3	4.5	6	0.5	1.5	3	4.5	6	LSD	Prob
Crumbly/Dry	0.18	0.07	0.06	0.10	0.06	-0.12	-0.11	-0.17	0.01	- 0.07	0.1063	0.0497
Sour/Bitter/ Metallic	-0.04	-0.03	-0.03	-0.07	-0.09	0.10	0.05	0.06	-0.01	0.06	0.1556	0.9315
Potato/Earthy	0.04	0.01	0.02	-0.01	-0.03	0.02	0.02	-0.03	0.03	- 0.05	0.1579	0.9464
Hard/Savoury	-0.01	-0.01	0.10	-0.08	-0.11	0.01	0.07	0.00	0.04	- 0.02	0.1153	0.0743
Sweet/Intense	-0.23	-0.11	-0.09	-0.04	-0.07	0.09	0.05	0.11	0.08	0.21	0.1286	0.1639
Off Notes	-0.06	-0.05	-0.05	0.01	0.00	0.13	-0.04	-0.07	0.09	0.03	0.1766	0.4821
Bad Appearance	0.04	-0.03	-0.07	0.05	-0.12	0.11	0.07	-0.08	-0.02	0.05	0.1858	0.3998
Aromatic	0.04	0.02	0.01	-0.06	-0.02	0.03	0.01	-0.01	0.02	- 0.04	0.2334	0.9729

TABLE A15. TIME- CO_2 INTERACTION SCORE SUMMARY

Crumbly/Dry	CO_2	Untreated	Ethylene
	0.5	0.1774	-0.1247
	1.5	0.0714	-0.1093
	3	0.0609	-0.169
	4.5	0.0991	0.0067
	6	0.0559	-0.0684

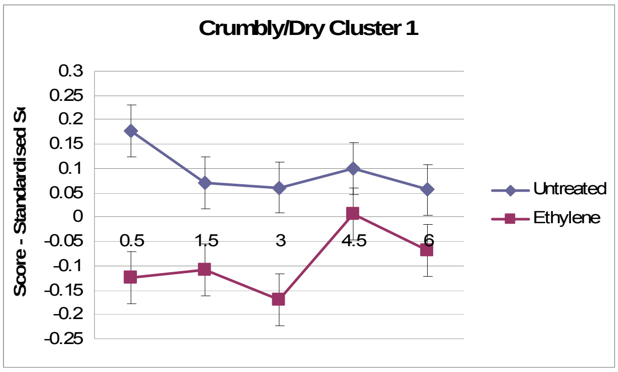


FIGURE A27. ETHYLENE- CO_2 INTERACTION SCORE: CRUMBLY/DRY

9.1.13.6. Variety – Ethylene interaction

	Estima		Marfona		Maris Piper			
	Untreated	**Ethylene**	**Untreated**	**Ethylene**	**Untreated**	**Ethylene**	**LSD**	**Prob**
Crumbly/Dry	0.02	-0.14	-0.40	-0.51	0.67	0.37	0.08	0.0051
Sour/Bitter/Metallic	-0.10	0.06	0.03	0.18	-0.09	-0.08	0.12	0.1257
Potato/Earthy	0.17	0.10	-0.19	-0.11	0.04	-0.01	0.12	0.2211
Hard/Savoury	-0.06	-0.02	0.00	-0.02	0.00	0.11	0.09	0.1300
Sweet/Intense	-0.25	-0.11	0.28	0.61	-0.35	-0.18	0.10	0.0191
Off Notes	-0.11	0.00	-0.05	0.08	0.07	0.01	0.14	0.0975
Bad Appearance	-0.22	-0.22	0.01	0.06	0.13	0.24	0.14	0.5839
Aromatic	0.11	0.00	-0.09	-0.04	-0.03	0.04	0.18	0.3385

TABLE A16. VARIETY-ETHYLENE INTERACTION SCORE SUMMARY

Crumbly/Dry

	Estima	Marfona	Maris Piper
Untreated	0.015	-0.4026	0.6665
Ethylene	-0.1428	-0.5089	0.3728

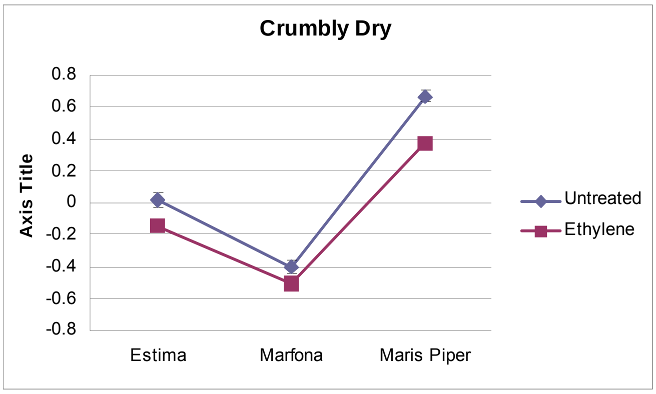


FIGURE A28. VARIETY-ETHYLENE INTERACTION SCORE: CRUMBLY/DRY

Sweet/Intense

	Estima	Marfona	Maris Piper
Untreated	-0.2541	0.2798	-0.3493
Ethylene	-0.1078	0.6117	-0.1804

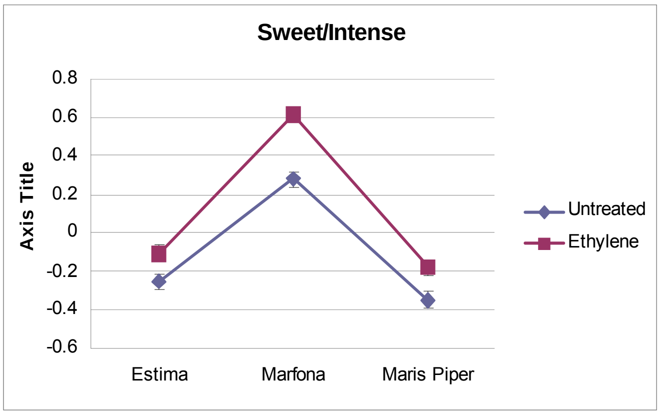


FIGURE A29. VARIETY-ETHYLENE INTERACTION SCORE: SWEET/INTENSE

9.1.13.7. CO_2 – Variety interaction

	0.50			1.50			3.00			4.50			6.00				
	Estima	**Marfona**	**Maris Piper**	**Estima**	**Marfona**	**Maris Piper**	**Estima**	**Marfona**	**Maris Piper**	**Estima**	**Marfona**	**Maris Piper**	**Estima**	**Marfona**	**Maris Piper**	**LSD**	**Prob**
Crumbly/ Dry	-0.07	-0.42	0.57	-0.11	-0.44	0.50	-0.10	-0.48	0.41	0.01	-0.46	0.62	-0.05	-0.47	0.50	0.13	0.5894
Sour/Bitter /Metallic	0.00	0.17	-0.07	-0.01	0.09	-0.06	-0.01	0.14	-0.08	-0.07	0.04	-0.08	-0.02	0.10	-0.13	0.19	0.9918
Potato/Earthy	0.12	-0.08	0.05	0.15	-0.16	0.03	0.14	-0.15	-0.01	0.19	-0.20	0.04	0.07	-0.16	-0.03	0.19	0.9674
Hard/ Savoury	-0.01	-0.01	0.02	-0.04	0.06	0.06	0.01	0.04	0.10	-0.08	-0.03	0.05	-0.10	-0.12	0.03	0.14	0.8925
Sweet/ Intense	-0.23	0.33	-0.31	-0.20	0.42	-0.30	-0.15	0.46	-0.27	-0.15	0.49	-0.29	-0.17	0.53	-0.14	0.16	0.8315
Off Notes	-0.05	0.09	0.07	-0.13	-0.01	0.00	-0.10	0.04	-0.12	0.02	0.01	0.11	-0.02	-0.04	0.12	0.22	0.7017
Bad Appearance	-0.17	0.13	0.27	-0.26	0.19	0.13	-0.31	-0.10	0.18	-0.16	-0.05	0.24	-0.22	0.01	0.11	0.23	0.4632
Aromatic	0.13	-0.05	0.03	0.11	-0.14	0.06	-0.04	0.01	0.04	0.09	-0.09	-0.07	-0.02	-0.05	-0.03	0.29	0.8772

TABLE A17. CO_2–VARIETY INTERACTION SCORE SUMMARY

9.1.13.8. Time, variety, Ethylene interaction

	January						June							
	Estima		Marfona		Maris Piper		Estima		Marfona		Maris Piper			
	Untreated	Ethylene	Untreated	Ethylene	Untreated	Ethylene	Untreated	Ethylene	Untreated	Ethylene	Untreated	Ethylene	LSD	Prob
Crumbly/Dry	0.04	-0.26	-0.33	-0.54	0.69	0.07	-0.01	-0.02	-0.47	-0.47	0.64	0.68	0.12	0.0004
Sour/Bitter/ Metallic	-0.07	0.23	0.23	0.33	0.03	0.04	-0.14	-0.12	-0.16	0.04	-0.20	-0.21	0.17	0.0854
Potato/Earthy	0.27	0.15	-0.18	0.01	-0.01	0.07	0.06	0.06	-0.20	-0.23	0.09	-0.08	0.17	0.0681
Hard/Savoury	0.12	0.21	0.15	0.23	0.22	0.49	-0.24	-0.26	-0.14	-0.27	-0.22	-0.27	0.13	0.2279
Sweet/Intense	-0.30	-0.06	0.22	0.61	-0.30	-0.07	-0.21	-0.15	0.34	0.62	-0.40	-0.29	0.14	0.8891
Off Notes	-0.12	0.02	0.06	0.08	0.28	0.06	-0.10	-0.01	-0.15	0.08	-0.14	-0.05	0.19	0.1919
Bad Appearance	-0.27	-0.29	0.06	0.28	0.24	0.53	-0.17	-0.15	-0.03	-0.15	0.03	-0.05	0.20	0.0782
Aromatic	0.12	-0.09	-0.35	-0.13	-0.21	0.03	0.10	0.10	0.18	0.06	0.15	0.05	0.26	0.0556

TABLE A18. TIME, VARIETY, ETHYLENE INTERACTION SCORE SUMMARY

9.1.13.9. Time, Ethylene, CO2 interaction

	January										June											
	Untreated					Ethylene					Untreated					Ethylene						
	0.5	1.5	3	4.5	6	0.5	1.5	3	4.5	6	0.5	1.5	3	4.5	6	0.5	1.5	3	4.5	6	LSD	Prob
Crumbly/Dry	0.29	0.09	-0.07	0.14	0.22	-0.36	-0.34	-0.36	-0.19	0.03	0.06	0.06	0.19	0.06	-0.11	0.11	0.12	0.03	0.20	-0.16	0.15	0.0004
Sour/Bitter/ Metallic	0.17	0.11	0.11	-0.02	-0.05	0.28	0.16	0.20	0.13	0.21	-0.24	-0.17	-0.17	-0.12	-0.14	-0.08	-0.07	-0.08	-0.14	-0.10	0.22	0.6057
Potato/Earthy	0.03	0.05	0.01	0.00	0.05	0.08	0.08	0.09	0.07	0.04	0.05	-0.04	0.03	-0.02	-0.11	-0.05	-0.04	-0.16	-0.02	-0.14	0.22	0.7988
Hard/Savoury	0.17	0.15	0.35	0.10	0.03	0.27	0.43	0.25	0.35	0.23	-0.18	-0.18	-0.15	-0.25	-0.24	-0.25	-0.30	-0.25	-0.28	-0.26	0.16	0.1766
Sweet/Intense	-0.30	-0.08	0.02	-0.08	-0.19	0.18	0.12	0.18	0.13	0.18	-0.16	-0.14	-0.21	0.00	0.05	0.00	-0.02	0.04	0.02	0.25	0.18	0.2512
Off Notes	0.03	0.06	0.08	0.10	0.10	0.15	-0.03	0.02	0.14	-0.01	-0.15	-0.17	-0.17	-0.08	-0.09	0.12	-0.06	-0.16	0.05	0.08	0.25	0.9167
Bad Appearance	0.03	-0.05	-0.14	0.23	-0.05	0.30	0.21	0.04	0.01	0.29	0.04	-0.02	0.00	-0.14	-0.19	-0.08	-0.07	-0.20	-0.06	-0.18	0.26	0.0474
Aromatic	-0.21	-0.07	-0.05	-0.27	-0.15	-0.05	-0.07	0.00	-0.08	-0.13	0.30	0.10	0.08	0.15	0.10	0.10	0.08	-0.01	0.12	0.06	0.33	0.8670

TABLE A19. TIME, ETHYLENE,CO_2 INTERACTION SCORE SUMMARY

9.1.13.10. Time, Variety, CO_2 interaction

	January														
	0.5			1.5			3			4.5			6		
	Estima	Marfona	Maris Piper	Estima	Marfona	Maris Piper	Estima	Marfona	Maris Piper	Estima	Marfona	Maris Piper	Estima	Marfona	Maris Piper
Crumbly/Dry	-0.13	-0.38	0.41	-0.20	-0.45	0.28	-0.24	-0.51	0.10	-0.05	-0.46	0.44	0.07	-0.38	0.68
Sour/Bitter/Metallic	0.09	0.40	0.18	0.03	0.31	0.07	0.14	0.33	0.01	0.08	0.13	-0.05	0.06	0.22	-0.04
Potato/Earthy	0.09	0.00	0.07	0.28	-0.11	0.02	0.21	-0.08	0.02	0.27	-0.16	-0.01	0.20	-0.09	0.02
Hard/Savoury	0.19	0.17	0.31	0.22	0.31	0.36	0.23	0.20	0.48	0.10	0.23	0.35	0.07	0.05	0.26
Sweet/Intense	-0.28	0.25	-0.15	-0.20	0.43	-0.18	-0.09	0.57	-0.17	-0.11	0.45	-0.26	-0.21	0.37	-0.16
Off Notes	-0.19	0.13	0.33	-0.18	0.06	0.18	-0.03	0.23	-0.05	0.16	0.00	0.19	-0.02	-0.06	0.20
Bad Appearance	-0.34	0.27	0.57	-0.29	0.36	0.17	-0.37	-0.11	0.34	-0.25	0.15	0.47	-0.18	0.17	0.37
Aromatic	0.07	-0.31	-0.14	0.14	-0.32	-0.04	-0.02	-0.04	-0.02	-0.05	-0.32	-0.15	-0.08	-0.23	-0.10

	June																
	0.5			1.5			3			4.5			6				
	Estima	Marfona	Maris Piper	Estima	Marfona	Maris Piper	Estima	Marfona	Maris Piper	Estima	Marfona	Maris Piper	Estima	Marfona	Maris Piper	LSD	Prob
Crumbly/Dry	-0.01	-0.46	0.73	-0.02	-0.43	0.72	0.04	-0.44	0.73	0.06	-0.47	0.80	-0.17	-0.56	0.32	0.18	0.0167
Sour/Bitter/Metallic	-0.10	-0.06	-0.32	-0.05	-0.13	-0.19	-0.16	-0.04	-0.17	-0.23	-0.05	-0.12	-0.11	-0.02	-0.23	0.27	0.5481
Potato/Earthy	0.15	-0.17	0.03	0.03	-0.20	0.05	0.07	-0.22	-0.04	0.11	-0.24	0.08	-0.06	-0.24	-0.08	0.27	0.9130
Hard/Savoury	-0.20	-0.18	-0.26	-0.29	-0.18	-0.24	-0.22	-0.11	-0.28	-0.26	-0.28	-0.26	-0.27	-0.29	-0.19	0.20	0.7377
Sweet/Intense	-0.19	0.41	-0.47	-0.21	0.40	-0.43	-0.21	0.34	-0.38	-0.18	0.54	-0.33	-0.13	0.70	-0.12	0.22	0.4127
Off Notes	0.09	0.04	-0.18	-0.07	-0.09	-0.19	-0.17	-0.15	-0.18	-0.12	0.02	0.04	-0.02	-0.03	0.03	0.31	0.0654
Bad Appearance	0.00	-0.01	-0.04	-0.23	0.01	0.09	-0.25	-0.08	0.02	-0.07	-0.24	0.02	-0.26	-0.15	-0.15	0.32	0.2481
Aromatic	0.18	0.21	0.20	0.08	0.04	0.15	-0.07	0.06	0.10	0.24	0.15	0.01	0.05	0.14	0.04	0.40	0.9865

TABLE A20. TIME, VARIETY,CO_2 INTERACTION SCORE SUMMARY

9.1.14. Assessment 1 Bar charts

Aroma attributes

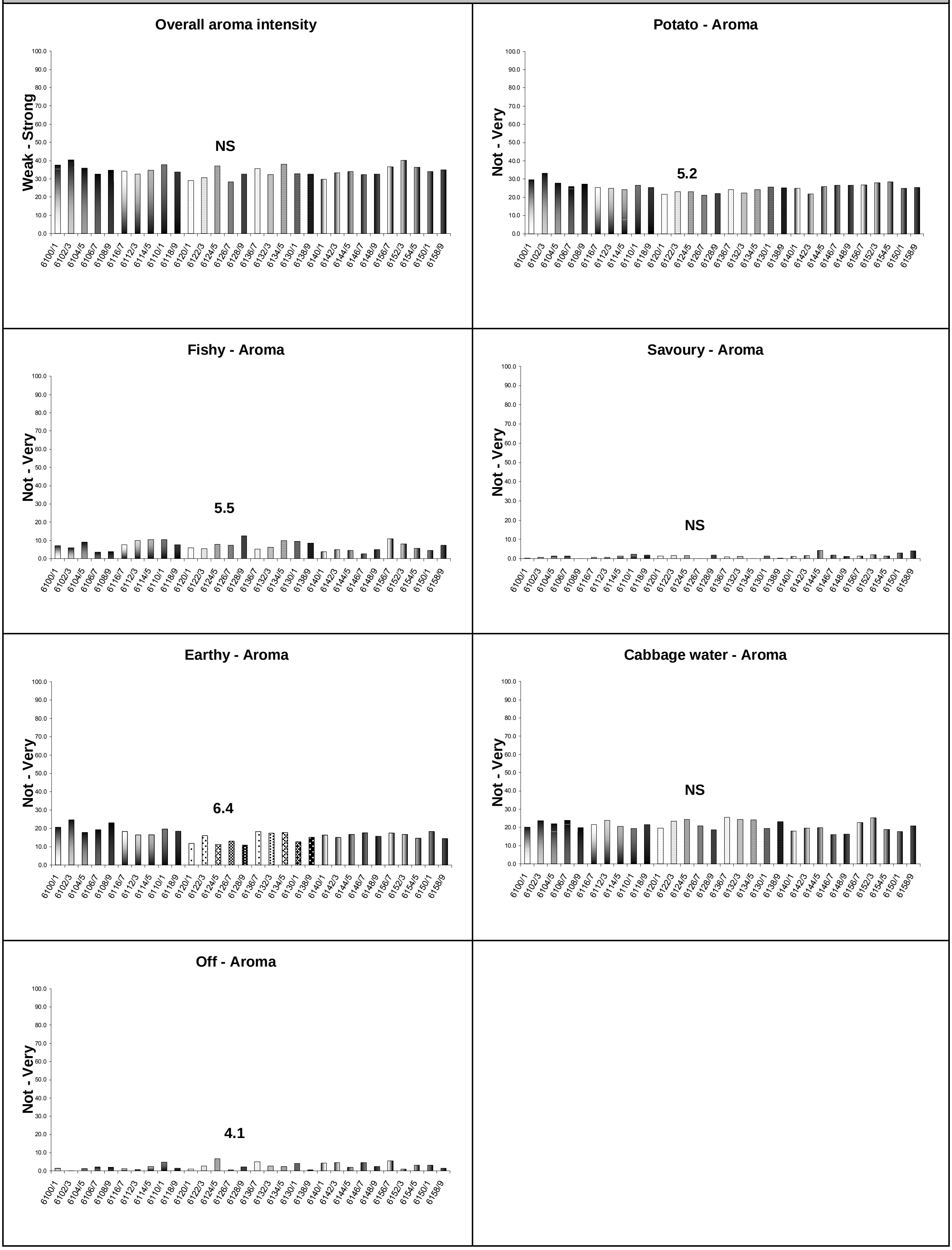


FIGURE A30. ASSESSMENT 1 AROMA ATTRIBUTES

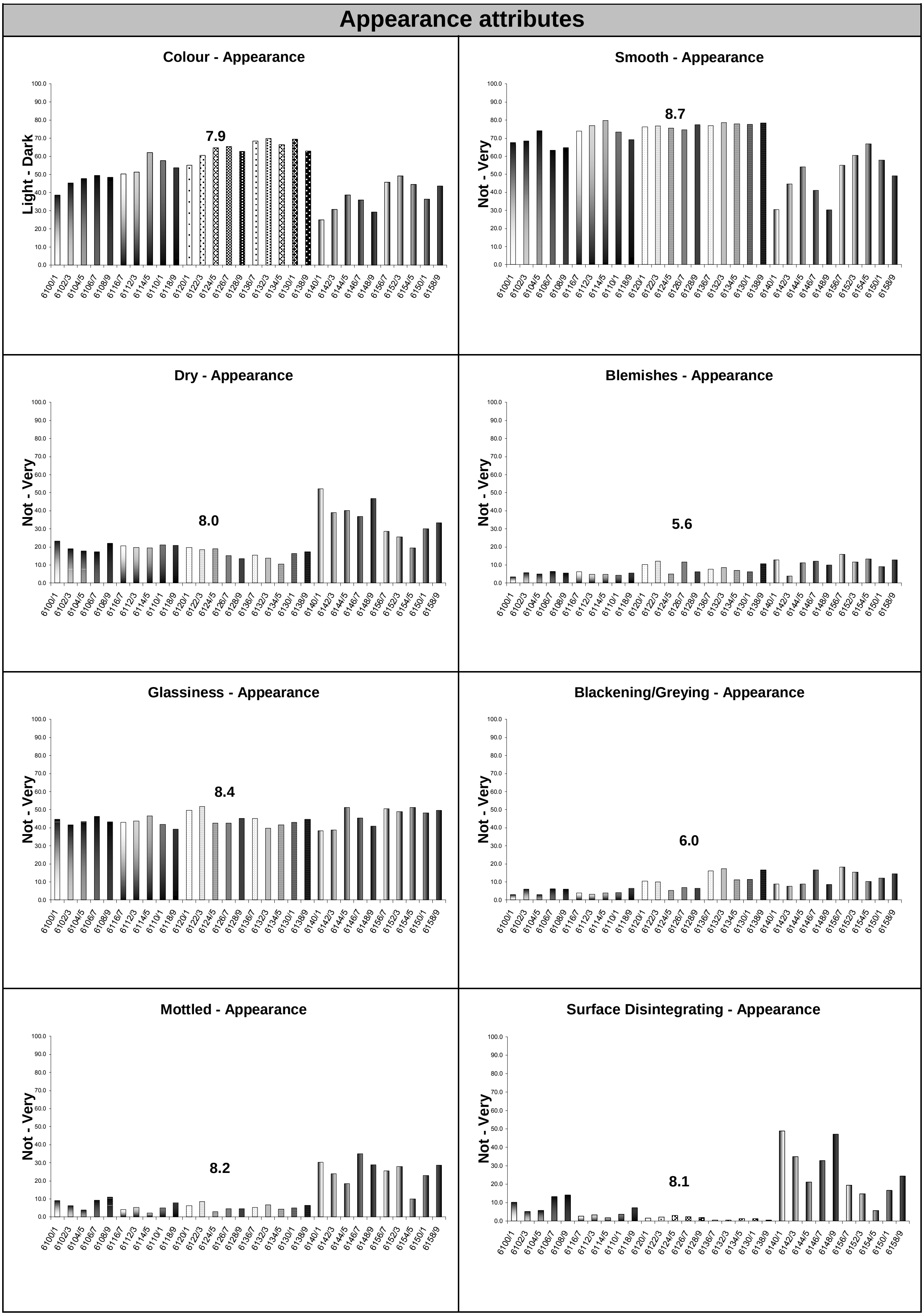


FIGURE A31. ASSESSMENT 1 APPEARANCE ATTRIBUTES

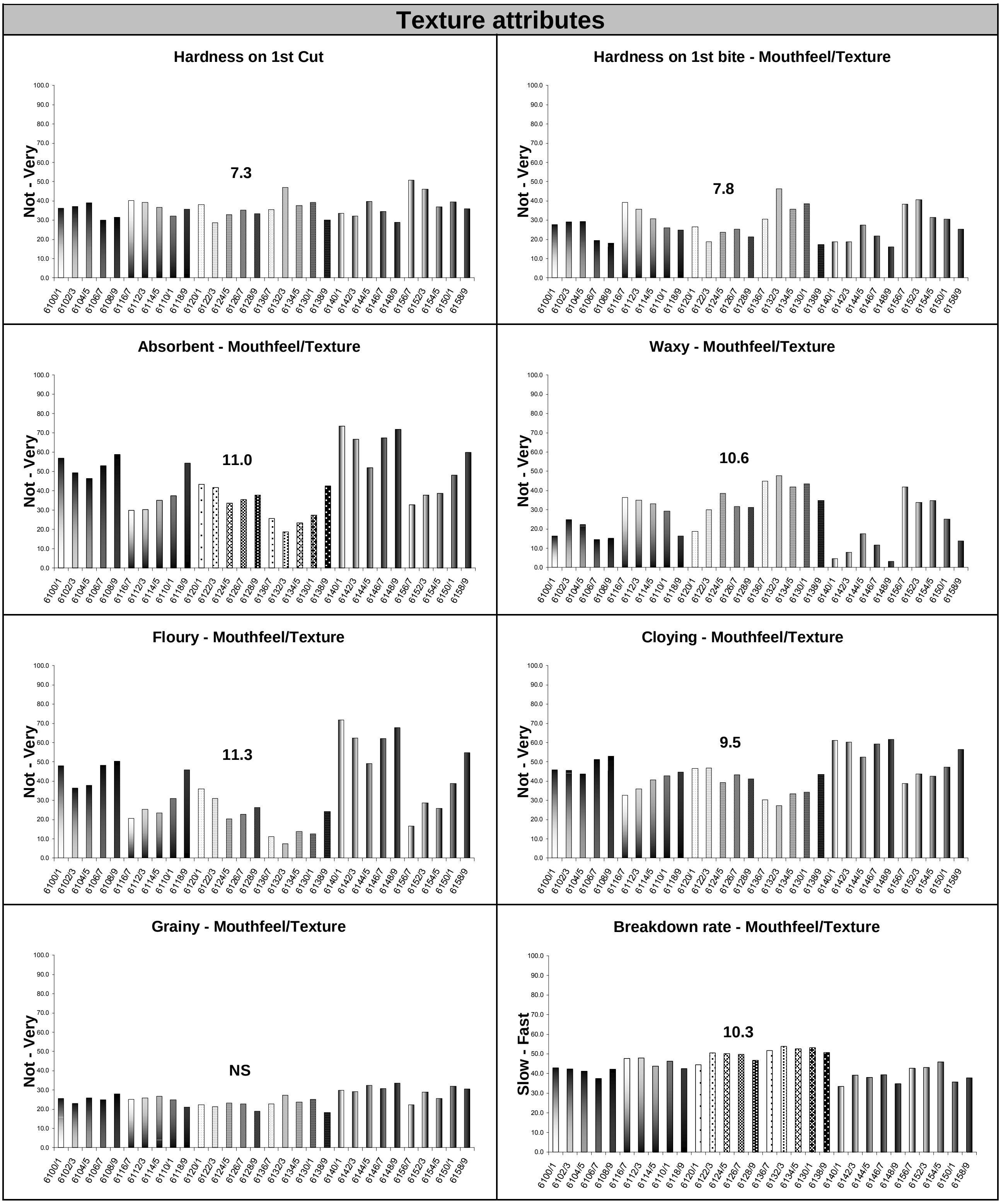


FIGURE A32. ASSESSMENT 1 TEXTURE ATTRIBUTES

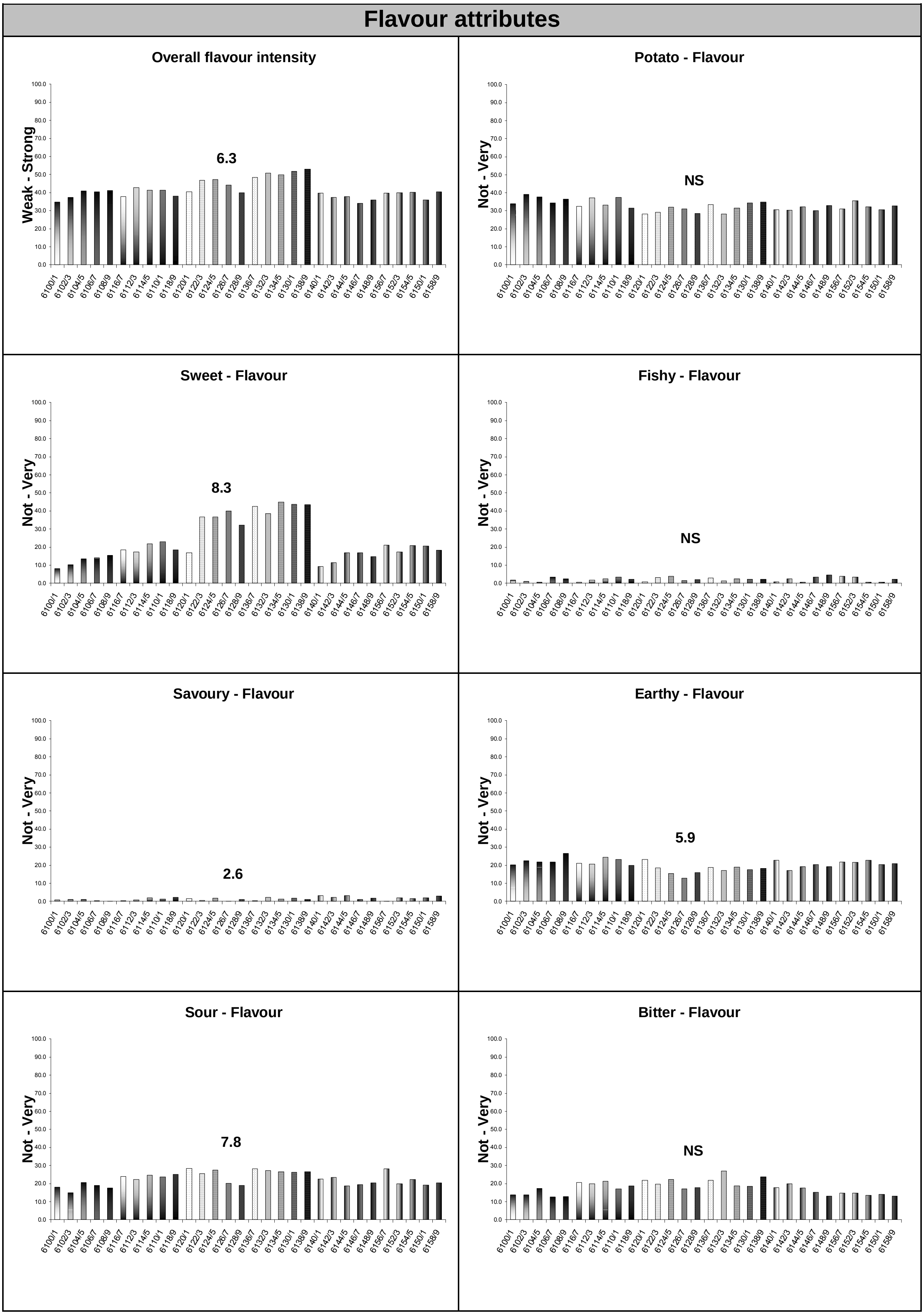
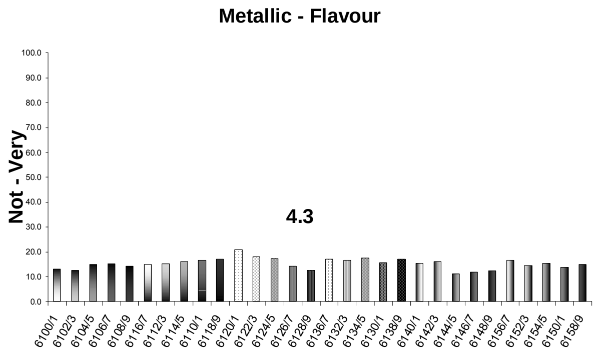
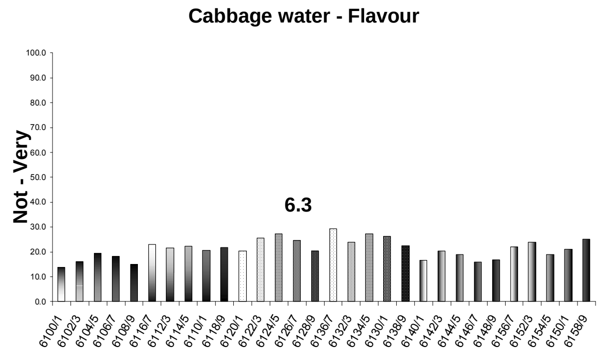


FIGURE A33. ASSESSMENT 1 FLAVOUR ATTRIBUTES

Flavour attributes (continued)





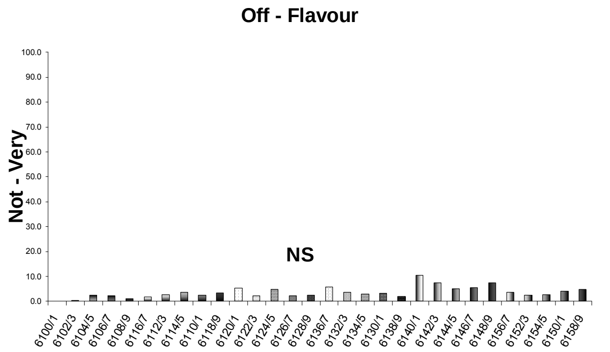
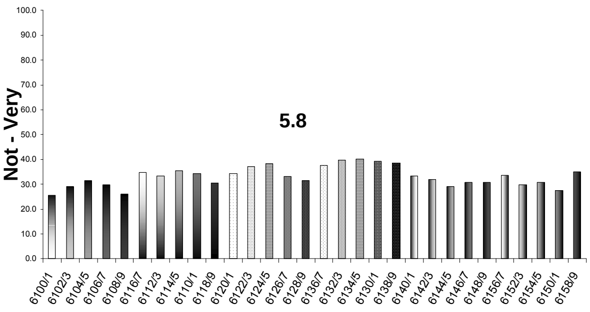


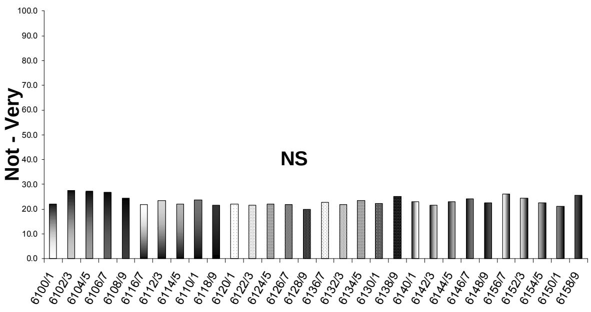
FIGURE A33. ASSESSMENT 1 FLAVOUR ATTRIBUTES (CONTINUED)

Aftertaste attributes

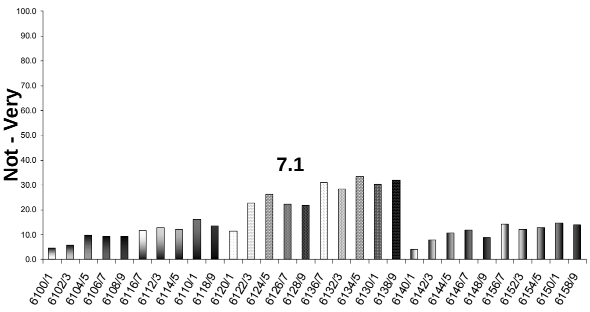
Overall aftertaste intensity



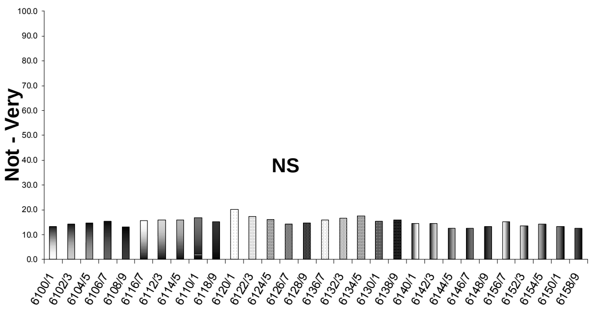
Potato - Aftertaste



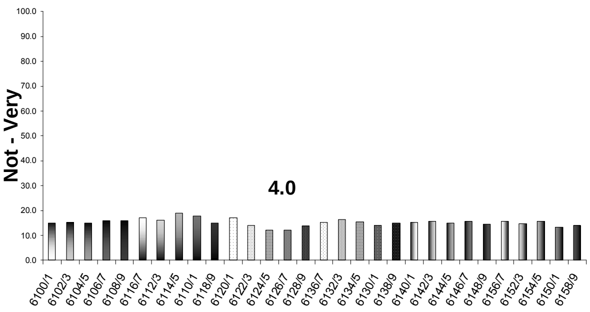
Sweet - Aftertaste



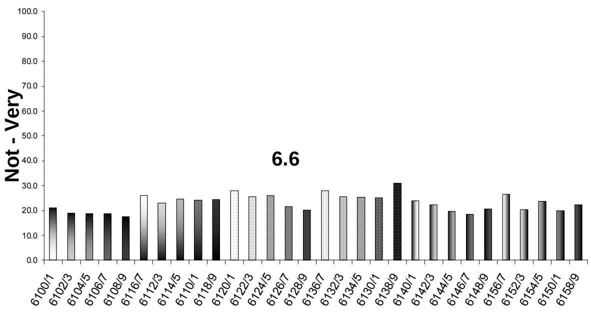
Metallic - Aftertaste



Earthiness - Aftertaste



Sourness - Aftertaste



Bitter - Aftertaste

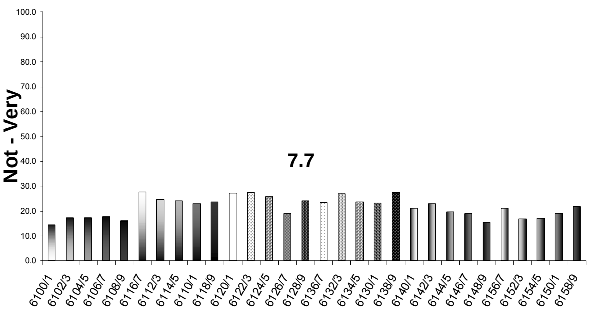


FIGURE A34. ASSESSMENT 1 AFTERTASTE ATTRIBUTES

Afterfeel attributes (continued)

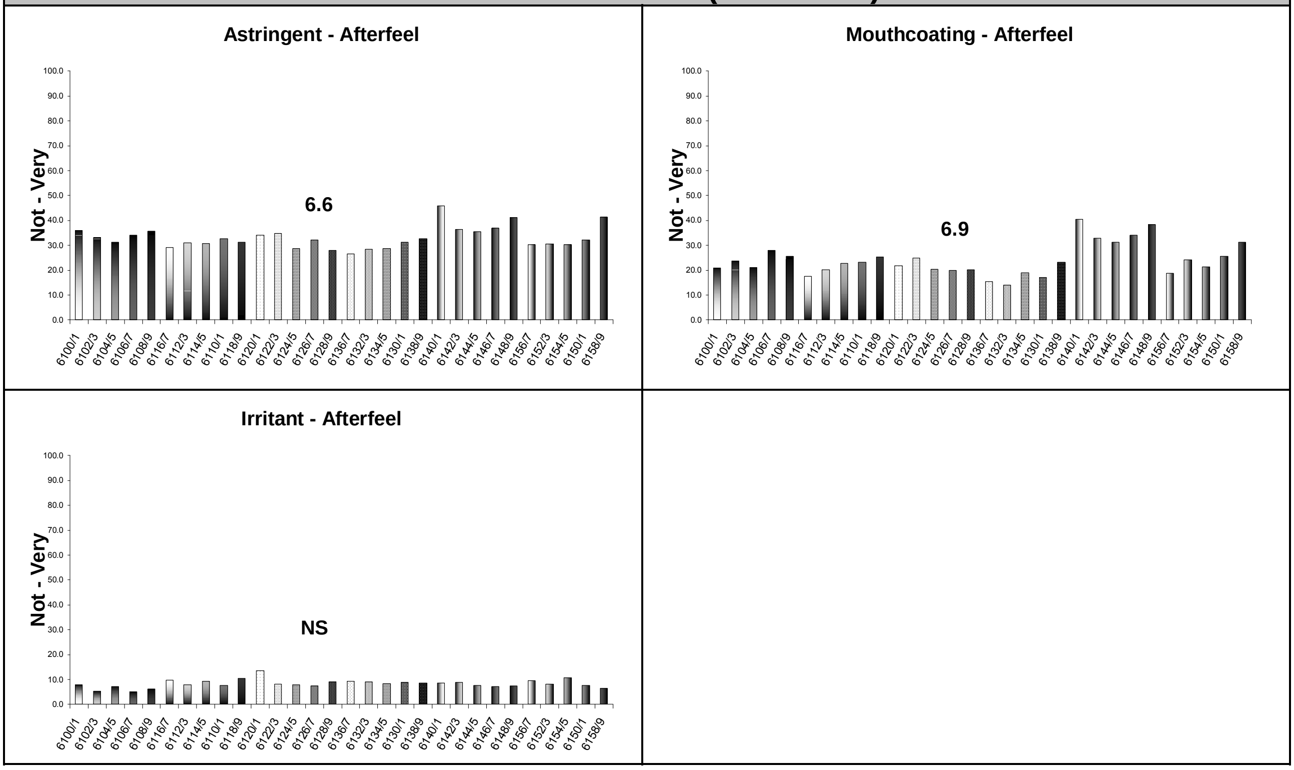
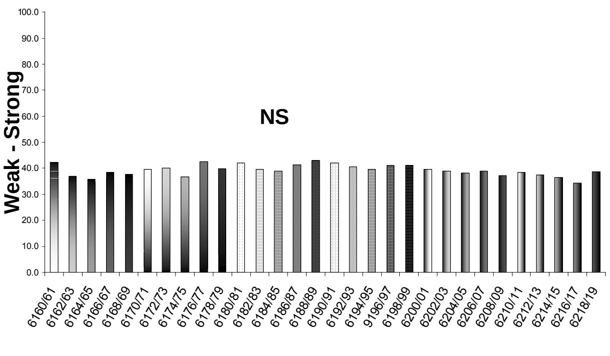


FIGURE A34. ASSESSMENT 1 AFTERTASTE ATTRIBUTES (CONTINUED)

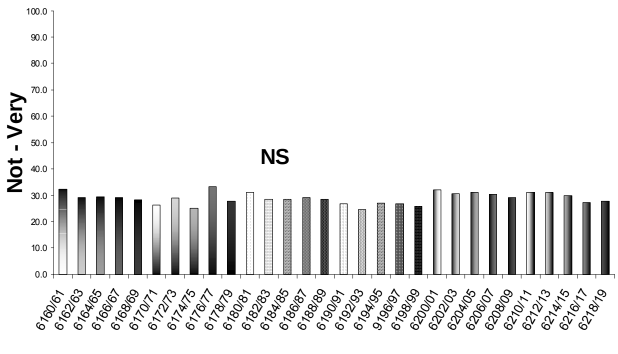
9.1.15. Assessment 2 Bar charts

Aroma attributes

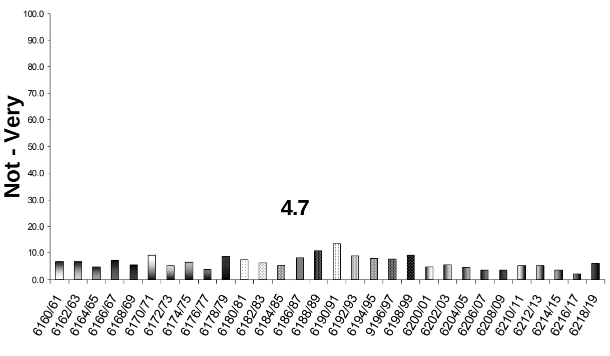
Overall aroma intensity



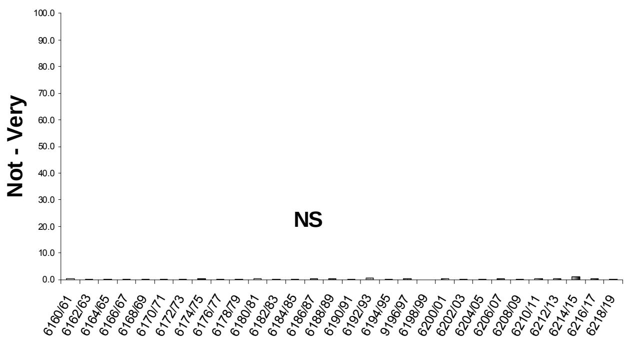
Potato - Aroma



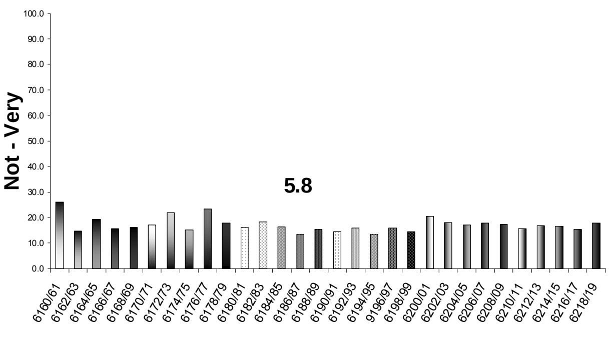
Fishy - Aroma



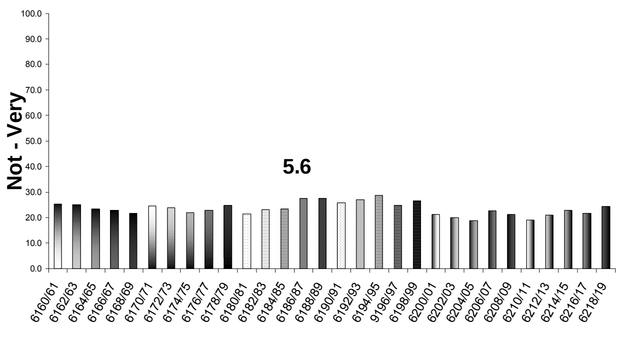
Savoury - Aroma



Earthy - Aroma



Cabbage water - Aroma



Off - Aroma

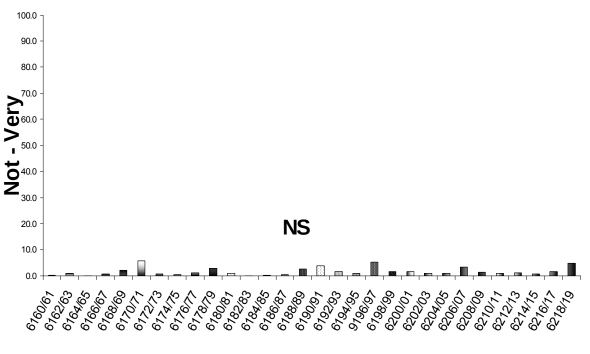
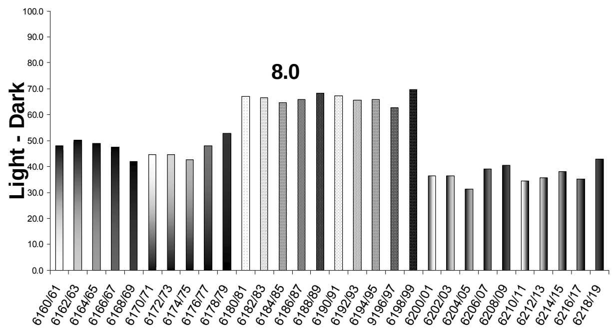


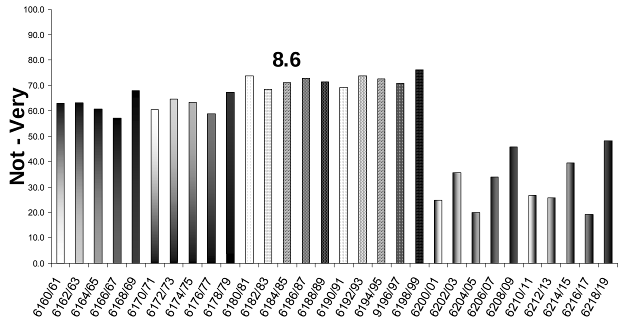
FIGURE A35. ASSESSMENT 2 AROMA ATTRIBUTES

Appearance attributes

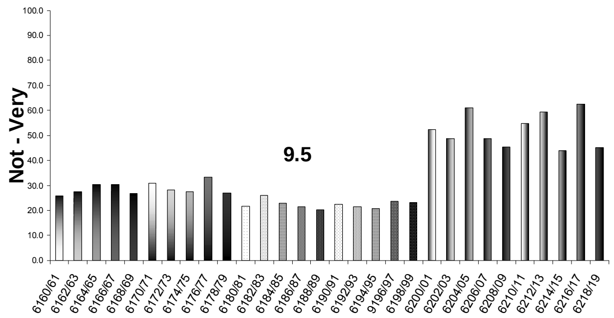
Colour - Appearance



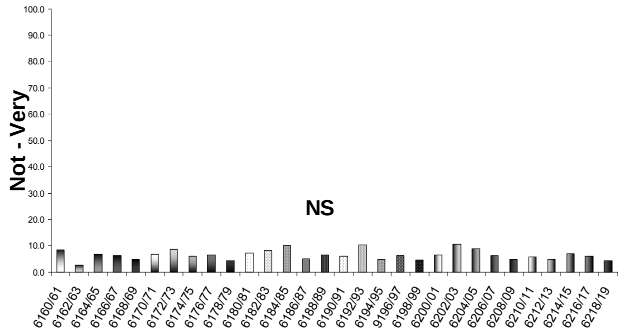
Smooth - Appearance



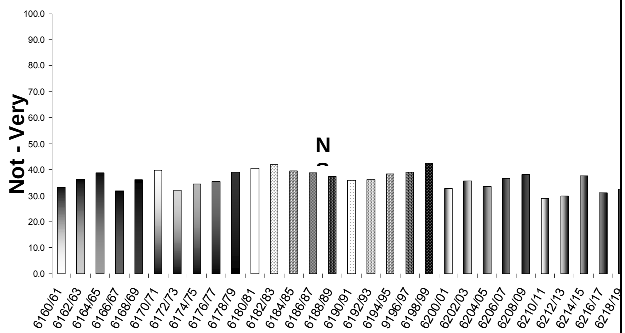
Dry - Appearance



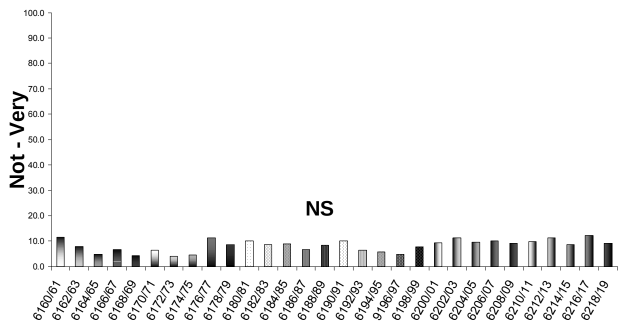
Blemishes - Appearance



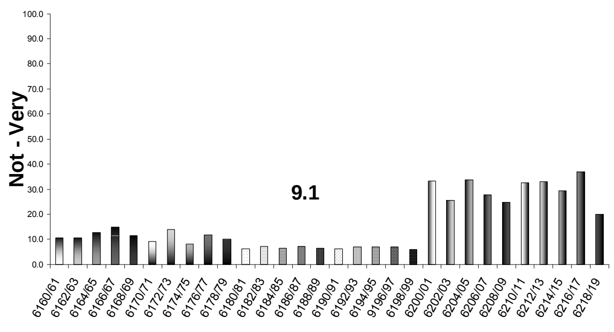
Glassiness - Appearance



Blackening/Greying - Appearance



Mottled - Appearance



Surface Disintegrating - Appearance

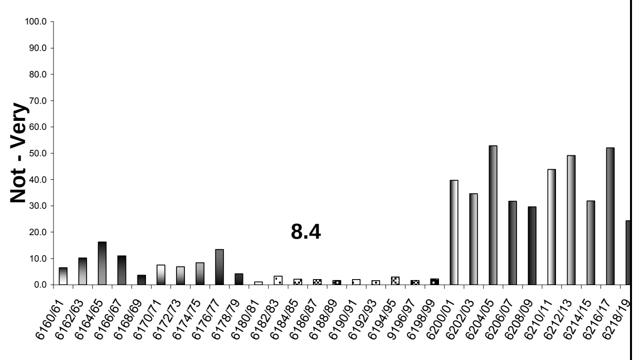


FIGURE A36. ASSESSMENT 2 APPEARANCE ATTRIBUTES

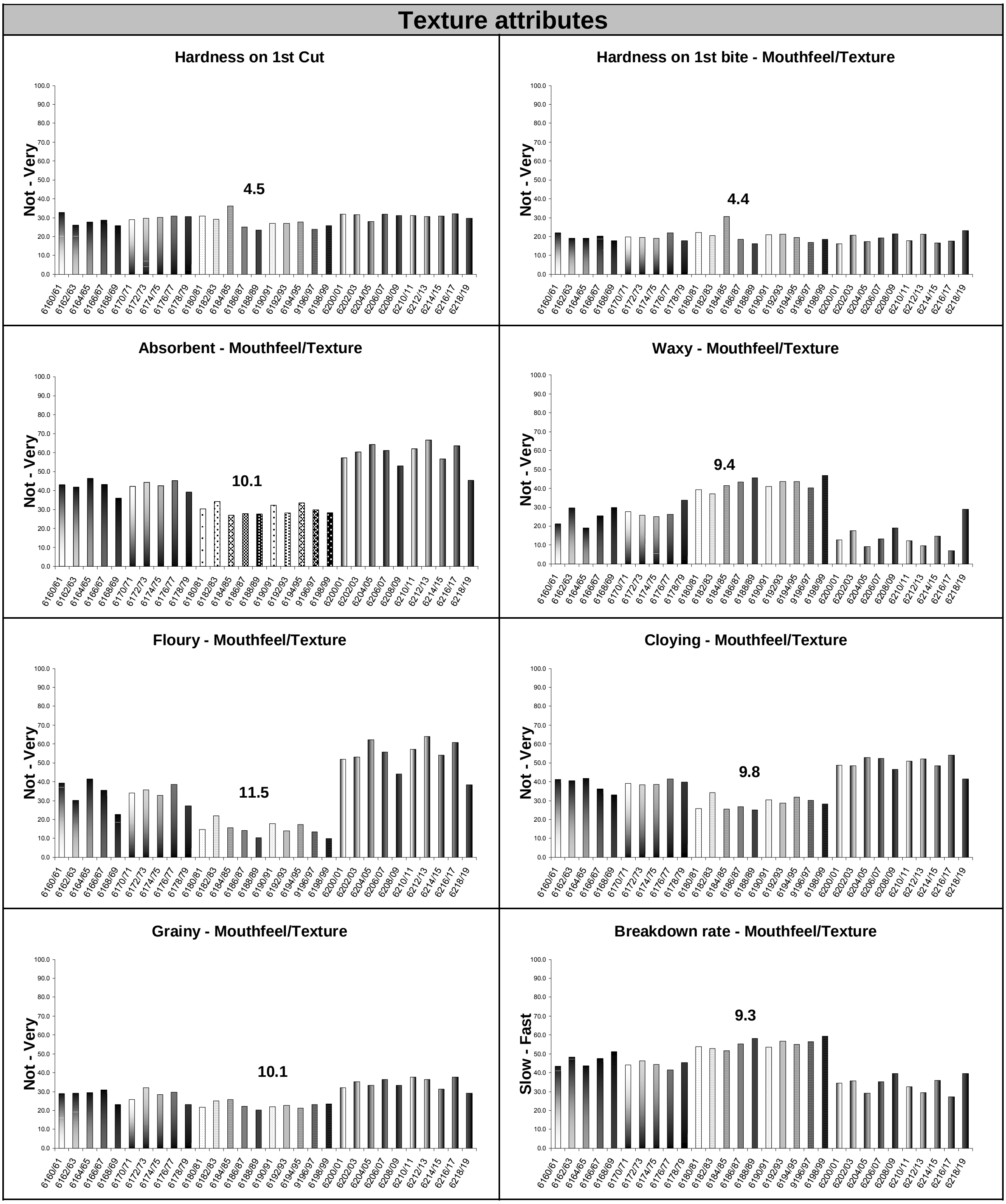


FIGURE A37. ASSESSMENT 2 TEXTURE ATTRIBUTES

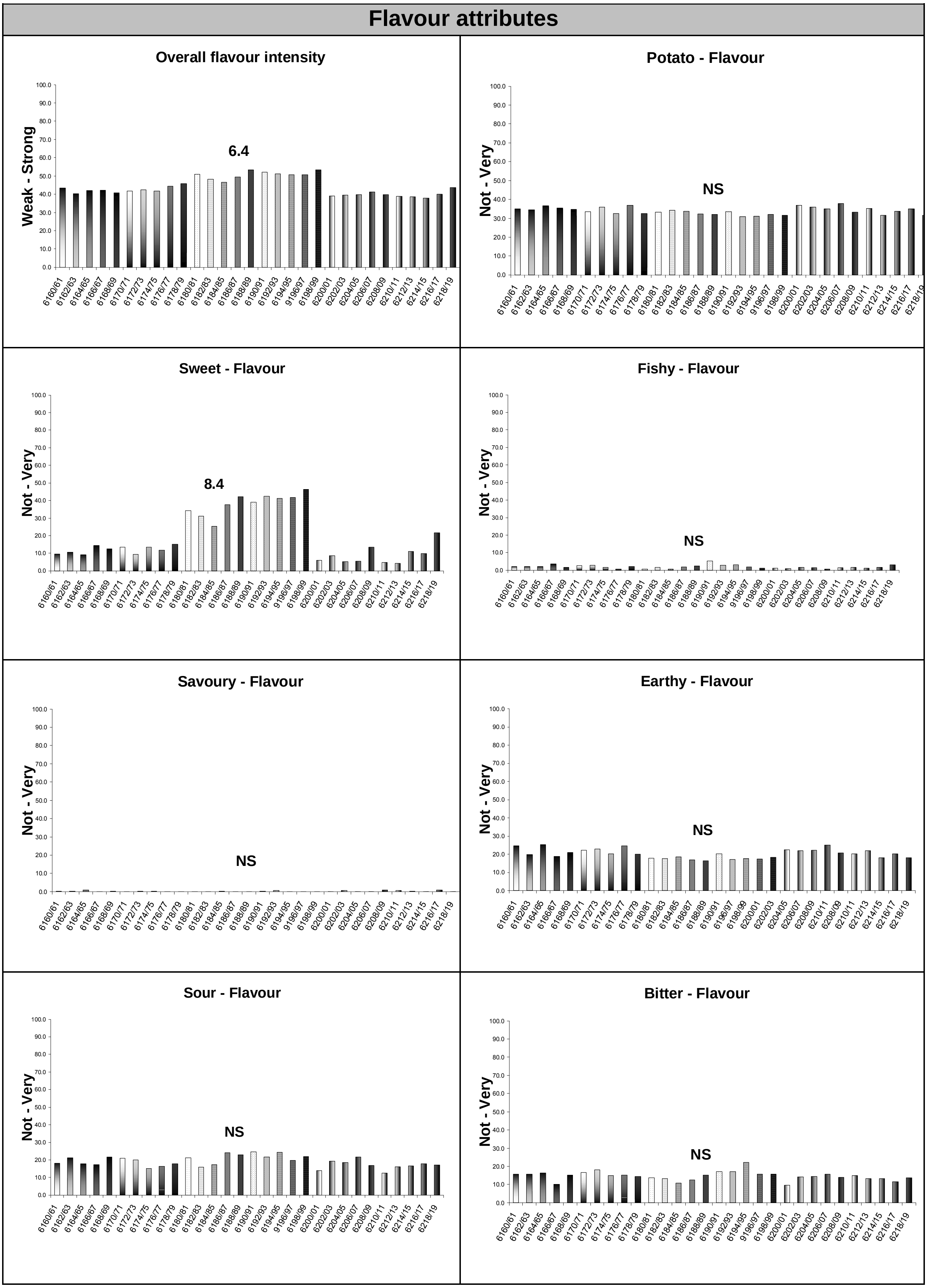
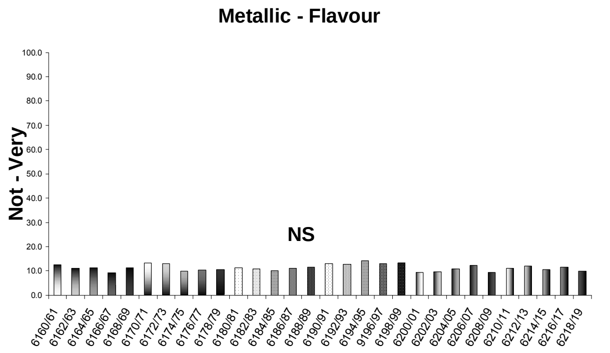
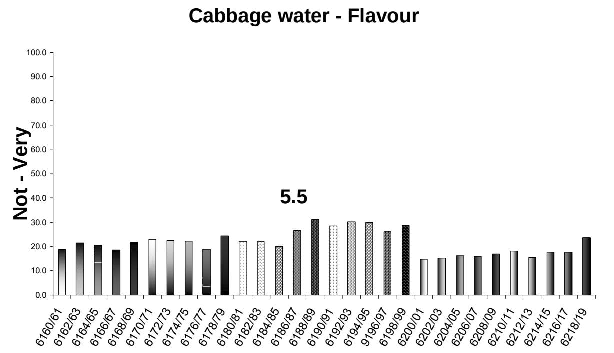


FIGURE A38. ASSESSMENT 2 FLAVOUR ATTRIBUTES

Flavour attributes (continued)





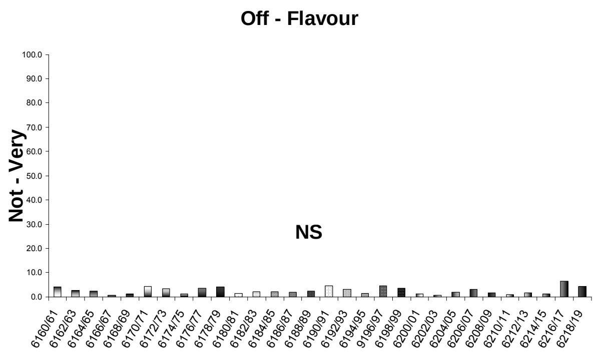


FIGURE A38. ASSESSMENT 2 FLAVOUR ATTRIBUTES (CONTINUED)

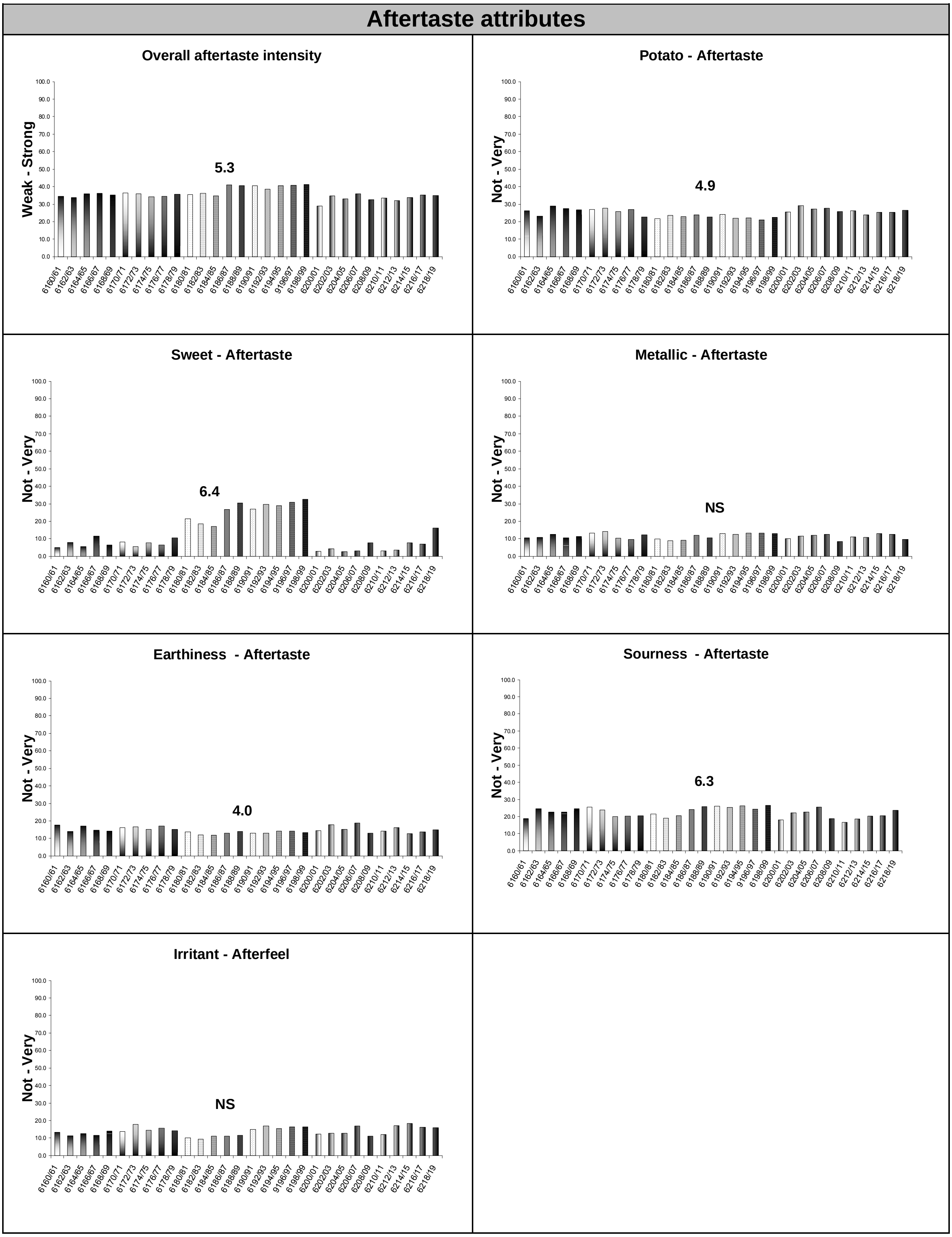


FIGURE A39. ASSESSMENT 2 AFTERTASTE ATTRIBUTES

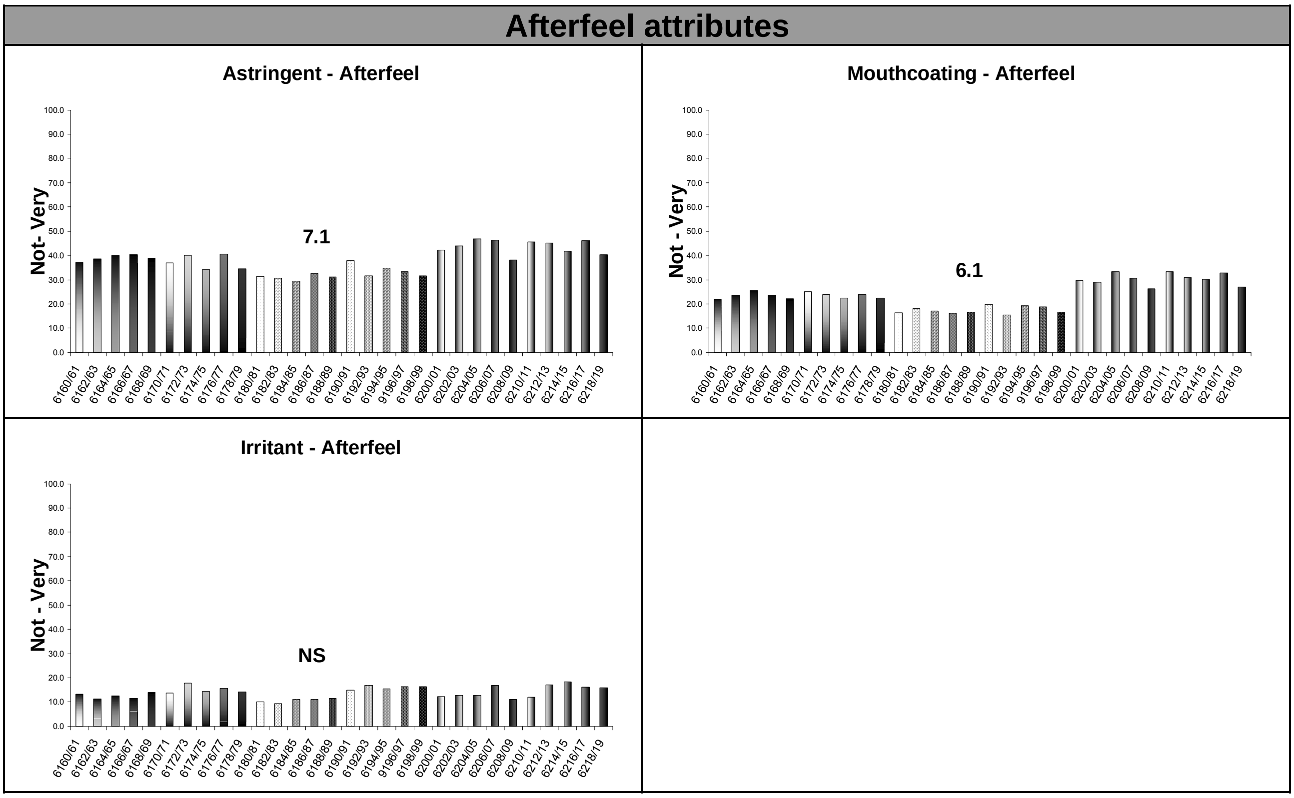


FIGURE A40. ASSESSMENT 2 AFTERFEEL ATTRIBUTES

10. ANNEX 2 LFI 2008-09 REPORT ON STORE CARBON DIOXIDE AND ETHYLENE LEVEL EFFECTS ON POTATO FLAVOUR AND TEXTURE CHARACTERISTICS TASTE AND TEXTURE ASSESSMENTS

10.1.1. Samples

All samples were supplied by Sutton Bridge in brown paper sacks with codes as detailed below. They were delivered on the 19th January 2009 for assessment 1 and 15th June 2009 for assessment 2.

For details of the potato varieties supplied see Table A21 below.

Assessment 1	Assessment 2	Variety	% CO_2	Ethylene
1	1	Estima	Ambient	minus
2	2	Estima	1.5	minus
3	3	Estima	4.5	minus
4	4	Estima	Ambient	plus
5	5	Estima	1.5	plus
6	6	Estima	4.5	plus
7	7	Marfona	Ambient	minus
8	8	Marfona	1.5	minus
9	9	Marfona	4.5	minus
10	10	Marfona	Ambient	plus
11	11	Marfona	1.5	plus
12	12	Marfona	4.5	plus
13	13	M. Piper	Ambient	minus
14	14	M. Piper	1.5	minus
15	15	M. Piper	4.5	minus
16	16	M. Piper	Ambient	plus
17	17	M. Piper	1.5	plus
18	18	M. Piper	4.5	plus

TABLE A21: POTATO SAMPLES EVALUATED

10.1.2. Sensory Panel

Assessors drawn from the trained sensory panel at Leatherhead took part in this experiment. All assessors have been trained in the sensory evaluation of an extensive range of food and beverage products and were familiarised with the Potato Council potato references in January and June 2009 prior to experimental assessment, as described below.

10.1.3. Preparation

Potatoes were washed, peeled, rinsed and then cut into pieces. Portions achieved from each potato was dependent on the potato size, small potatoes being sliced into two and the large potatoes being cut into six or sometimes eight. The potatoes were cut up as consistently as possible, so that the pieces of potato were as uniform as possible, to enable them to be cooked to the same degree. The portioned potatoes were cooked using Tefal Steam Cuisine Ultra Compact 3-tier steamers, model series

S04. The potato pieces were cooked until soft, which was judged by penetration with a sharp knife. Typically the steaming time was 25-30 minutes.

10.1.4. Product Profiling

A sensory profile was developed based on the principles of quantitative descriptive analysis (QDA) and produced at the start of the project in January 2008

10.1.5. Vocabulary generation and training

Assessors evaluated each of the samples independently and provided a detailed sensory description of the product. The panel then discussed their views and generated a consensus vocabulary, which consisted of specific attributes and definitions. The final glossary against which the 2008 and 2009 products were scored is detailed in Tables A2 and A3 of the 2008 report. References were identified to clarify particular sensory attributes and these are shown in Table 3.

10.1.6. Design

All potato samples were tested in triplicate, whereby all assessors evaluated the eighteen potatoes three times at each time point. For practical and consistent presentation of the potatoes, each replicate was divided in ten sessions, each comprising three different potato samples, presented in a balanced presentation order. Over the three replicates each potato variant was seen with six other samples. Replicates were presented over three days.

10.1.7. Assessment

Each assessor carried out individual evaluations of all the test samples. All 18 test samples were presented in a sequential monadic randomized fashion.

- All samples were presented to the assessors directly from the steamers.
- All samples were tested in triplicate.
- All assessments were carried out in separate booths at the LFI sensory facility.
- Assessors used line scales, varying from 0-100, to indicate intensity of attributes.
- Sensory data was collected using a computerized acquisition system, Compusense 5 vs. 4.8.

10.1.8. Data Analysis

The data from each panellist was pooled and analysed to determine the differences between the samples. The univariate analysis (examining each attribute) was carried out using ANOVA and Fisher's LSD (least significant difference) for multiple comparisons between samples. A significance level of 5% (95% confidence) was applied for measurement of statistical significant differences between samples. Additional data analysis was carried out to obtain Tukey's HSD (honest significant difference) as a more conservative method to measure significance differences. Tukeys HSD can be found in Appendix I. Most of the test refers to significance by Fisher's LSD, unless indicated. Data analysis was carried out using Senpaq version 3.9.

Further analysis to view the relationship between the samples and the attributes was carried out by pooling the data from the two assessment periods and using the multivariate statistical method known as Principal Component Analysis (PCA). Data was analysed using XLSTAT 2009.2.02

To determine if there was any interactions between the ethylene, time and the various levels of CO_2 used on the potato results, General Linear Modelling (GLM) was used (XLSTAT 2009.2.02.)

10.1.9. Results

The results are divided in to several sections. Tables of the samples' pooled numerical scores, along with the LSD and p Value are listed in tables A22 – A27. Tubers that were assessed in January are in tables 4- 6 and sample tested in June are in tables 7 – 9.

Summaries of each attribute and the potential trends are listed according to each modality and followed by a graphical image of the differences between the tubers during each assessment periods and collectively are shown after the attribute summary.

	Untreated			Treated				
	Ambient	**1.5**	**4.5**	**Ambient**	**1.5**	**4.5**	**LSD**	**p Value**
Aroma								
Overall aroma intensity	38.6	37.5	40.4	39.8	38.3	36.8	NS	0.3115
Potato	28.9	28.4	27.2	27.6	26.7	27.8	NS	0.7114
Fishy	3.1	2.0	2.7	2.2	4.0	1.5	NS	0.2933
Savoury	3.1	2.5	5.3	1.7	3.8	1.3	NS	0.2603
Earthy	23.2	15.3	18.3	15.9	18.2	19.8	5.2	**0.0413**
Cabbage water	21.9	22.5	21.2	23.7	22.6	20.0	NS	0.5550
Off	0.6	0.5	1.1	0.8	0.8	1.7	NS	0.7234
Appearance								
Colour	45.9	43.0	48.8	45.9	51.5	44.5	NS	0.0822
Smooth	67.3	61.9	65.0	58.6	63.1	61.0	5.3	**0.0323**
Dry	26.2	25.3	24.4	29.5	24.9	29.6	NS	0.2710
Blemishes	2.6	3.5	4.0	3.1	4.2	6.4	NS	0.0876
Glassiness	32.8	34.8	34.4	34.4	37.3	33.2	NS	0.3088
Blackening / Greying	4.4	8.3	3.0	2.4	4.5	7.7	4.5	**0.0489**
Mottled	6.3	8.0	6.7	8.6	10.4	11.7	NS	0.4724
Surface Disintegrating	5.7	11.4	10.6	12.1	10.3	10.8	NS	0.2157
Cut the potato into 2								
Hardness on 1st Cut	32.1	30.4	33.9	32.9	32.7	30.5	NS	0.4970
Texture/Mouthfeel								
Hardness on 1st bite	22.8	22.3	23.8	24.0	22.8	21.9	NS	0.9565
Absorbent	47.6	49.8	44.8	47.2	47.2	44.0	NS	0.3776
Waxy	25.9	21.8	26.9	20.9	24.7	27.6	4.9	**0.0491**
Floury	28.1	33.0	26.5	31.1	27.1	26.0	NS	0.1339
Cloying	40.6	39.3	41.5	39.8	42.0	37.6	NS	0.3676
Grainy	15.7	16.5	18.0	17.5	20.5	14.6	NS	0.2146
Breakdown rate	44.4	40.0	44.7	40.2	40.6	45.1	4.2	**0.0294**
Flavour								
Overall flavour intensity	40.6	38.7	42.1	39.5	38.7	38.6	NS	0.5302
Potato	33.0	32.0	32.5	32.9	30.3	30.1	NS	0.1581
Sweet	17.6	18.8	23.0	13.8	19.1	21.5	4.2	**0.0014**
Fishy	0.5	0.3	0.3	0.7	0.8	0.4	NS	0.6275
Savoury	2.8	0.5	1.6	1.9	1.6	1.1	NS	0.2801
Earthy	22.9	19.0	17.7	21.4	21.7	20.2	NS	0.4191
Sour	20.0	17.3	17.5	21.0	19.7	17.1	NS	0.4635
Bitter	15.7	14.4	13.0	14.6	14.2	14.0	NS	0.9393
Metallic	9.1	11.4	10.6	10.7	11.9	11.4	NS	0.7432
Cabbage water	18.7	20.3	21.9	21.1	19.1	18.8	NS	0.5554
Off	0.6	0.3	0.2	0.4	1.9	1.2	NS	0.4037
Aftertaste								
Overall aftertaste intensity	29.2	29.5	30.5	29.3	31.0	27.1	NS	0.1802
Potato	23.6	22.3	22.1	23.0	22.7	21.5	NS	0.7016
Sweet	12.1	12.1	17.3	10.6	14.8	15.5	3.1	**0.0005**
Metallic	8.8	10.5	9.6	10.3	10.7	8.8	NS	0.7209
Earthiness	15.5	13.2	12.2	15.3	15.8	14.1	NS	0.1774
Sourness	18.9	18.2	17.3	20.0	18.2	16.2	NS	0.5737
Bitter	14.5	14.7	14.5	14.7	15.8	13.1	NS	0.8977
Afterfeel								
Astringent	32.7	32.6	29.6	34.1	32.2	34.2	NS	0.1149
Mouthcoating	22.9	25.2	23.7	26.2	23.0	24.8	NS	0.1676
Irritant	3.6	4.3	4.6	5.0	5.2	3.8	NS	0.1149

LSD = Least Significant Differences, products with a difference in mean score higher then the LSD are significantly different in the represented attribute at the 5% significance level.

NS = No significance difference at 95% confidence level

TABLE A22: ESTIMA POTATO PROFILING (1)

	Untreated			Treated				
	Ambient	1.5	4.5	Ambient	1.5	4.5	LSD	P Value
Aroma								
Overall aroma intensity	35.6	37.5	37.1	38.8	35	35.2	NS	0.1438
Potato	26.1	24.8	25.4	26.9	27.5	26.2	NS	0.3681
Fishy	3.2	3.3	3.4	3.1	1.9	1.6	NS	0.2403
Savoury	2	2.3	4.8	3.9	3	1.3	NS	0.0968
Earthy	16.6	16.5	13.9	18.4	15.2	13.8	NS	0.1633
Cabbage water	20.2	21.1	19.7	19	16.4	19.6	NS	0.2435
Off	1.8	3.4	3.2	4.3	1.8	0.9	NS	0.3843
Appearance								
Colour	52.5	56.1	56.3	58.2	55.7	58.8	NS	0.0558
Smooth	68	66.8	67.6	71.1	64.7	70.2	NS	0.0516
Dry	22.2	23.6	21.3	22.1	24.3	21.3	NS	0.2954
Blemishes	4.4	5.1	5.5	6.4	9.3	4.5	NS	0.3049
Glassiness	31.4	30.5	32.5	33.4	31.2	30.9	NS	0.4287
Blackening / Greying	2	3	1.8	5.7	7.9	6	4.3	**0.0331**
Mottled	4.9	3.8	4	5.2	10.2	7.6	3.8	**0.0078**
Surface Disintegrating	5.4	6.6	4	3.4	5.8	4.2	NS	0.0961
Cut the potato into 2								
Hardness on 1st Cut	28.4	28.9	27.2	28.6	33.6	30.6	3.5	**0.0098**
Texture / Mouthfeel								
Hardness on 1st bite	16.3	17.3	16.7	17.2	21.8	14.9	3.1	**0.0013**
Absorbent	41.4	38.9	37.2	39.9	36.7	33	NS	0.0551
Waxy	22.9	26.8	21.5	23.9	26.4	29.7	5.2	**0.0319**
Floury	23.6	21.5	18	19.4	19.1	13.1	6.2	**0.0303**
Cloying	40.4	35.2	35.8	36	32.5	31.1	5.1	**0.0141**
Grainy	13.8	15.7	11.6	14.6	15.6	12.5	3.0	**0.0455**
Breakdown rate	44.8	44.8	47.3	46.3	50.1	52.3	4.9	**0.0163**
Flavour								
Overall flavour intensity	38.9	40.1	41	40	39.6	39.9	NS	0.8924
Potato	28.7	29.1	28.2	30.2	29.2	28.2	NS	0.6017
Sweet	19.1	20.6	26.4	21.6	24.5	26.9	4.3	**0.0017**
Fishy	1.2	1	0.6	1.4	0.4	0.7	NS	0.5336
Savoury	1.4	0.8	1.4	1.4	0.7	0.9	NS	0.5828
Earthy	20	17.4	15.7	19.3	15.4	15.4	3.5	**0.0282**
Sour	20.4	18.9	20.1	19.1	16.5	17.1	NS	0.4498
Bitter	14.9	16.4	16.5	16.2	14.4	13.6	NS	0.3114
Metallic	13.8	13.6	11.9	12.9	12.2	10.2	NS	0.2739
Cabbage water	19.7	20.1	18.3	19.7	19.5	21	NS	0.6736
Off	0.9	1.1	1	0.8	1.2	0.3	NS	0.8674
Aftertaste								
Overall aftertaste intensity	29	28.7	31.4	30.6	28.9	29.1	NS	0.4167
Potato	20.1	19.8	21.3	21.2	20.4	20.3	NS	0.5792
Sweet	14.3	13.5	18.5	14.9	16.7	19.8	3	**0.0004**
Metallic	13.1	10.9	11.8	11.8	10.6	9	NS	0.1923
Earthiness	12.9	11.1	10.7	12.5	11.8	10.5	NS	0.2420
Sourness	21.8	18.8	21.5	21.5	17.3	16.8	3.9	**0.0272**
Bitter	16.4	15.6	19.4	19.2	15.5	14.3	3.5	**0.0221**
Afterfeel								
Astringent	29.8	26.5	29.1	29.5	25.3	26.5	3.4	**0.0405**
Mouthcoating	22	20.3	22.1	22.8	18.4	18.6	2.4	**0.0006**
Irritant	6.2	6	6.5	6.2	4.4	4.3	NS	0.1877

LSD = Least Significant Differences, products with a difference in mean score higher then the LSD are significantly different in the represented attribute at the 5% significance level.

NS = No significance difference at 95% confidence level

TABLE A23: MARFONA POTATO PROFILING (1)

	Untreated			Treated				
	Ambient	1.5	4.5	Ambient	1.5	4.5	LSD	P Value
Aroma								
Overall aroma intensity	35.7	35.8	36.5	37	36.3	35.8	NS	0.9623
Potato	27.3	26.4	26.1	25.6	25.2	24.8	NS	0.6621
Fishy	2.2	2.6	1.4	2.5	3.2	1.4	NS	0.1723
Savoury	3.3	2.4	3.5	3.5	1.9	2.2	NS	0.6458
Earthy	13.3	14.6	16.3	16.3	13.7	13.8	NS	0.4739
Cabbage water	18.1	18.9	19.7	22.5	19.3	14	NS	0.0679
Off	1.5	1.5	0.8	1.9	0.4	4.7	NS	0.0901
Appearance								
Colour	38.7	35.3	36.2	36.3	36.9	31.9	NS	0.1489
Smooth	40.1	38	44	43.5	46.2	39.7	NS	0.2839
Dry	39.2	44.7	33.9	36	33.7	39.1	6.5	**0.0127**
Blemishes	5.7	2.5	1.3	4.1	4.5	4.5	NS	0.1137
Glassiness	27.8	29.6	29.7	28.2	28.7	29.1	NS	0.9161
Blackening / Greying	2.1	1.8	2.3	1.6	1.8	4.2	NS	0.4989
Mottled	11.9	12.2	12.8	12.7	11.2	14.7	NS	0.8057
Surface Disintegrating	30.6	32	30.3	27.8	23.9	28.9	NS	0.5513
Cut the potato into 2								
Hardness on 1st Cut	28.2	26.9	26.7	26.4	29.4	30.8	NS	0.2558
Texture								
Hardness on 1st bite	17.3	13.5	17.4	16.5	18.3	21.1	4.1	**0.0217**
Absorbent	54.9	62.5	55	56.2	55.8	58	NS	0.2096
Waxy	10.2	7.5	10.9	9.3	10.9	11.5	NS	0.6322
Floury	44.3	52.5	43	48.3	43.4	50	6.6	**0.0259**
Cloying	43.5	50.4	40.2	46	42.3	46.2	NS	0.0574
Grainy	20.4	21.9	18.3	18.4	19.3	21.9	NS	0.1923
Breakdown rate	47.8	44.5	49.1	43.6	42.8	44.3	NS	0.1209
Flavour								
Overall flavour intensity	38.5	38.1	38.4	38.3	40.4	37.8	NS	0.7135
Potato	28.9	29.2	30.8	29.5	30.8	27.9	NS	0.3631
Sweet	7.9	8.2	10.8	7.1	10.1	9	NS	0.3120
Fishy	1.6	0.3	0.6	0.3	0.6	1	NS	0.1088
Savoury	2.2	3.1	1.7	2.5	2.7	2.3	NS	0.4879
Earthy	14.8	14.3	16.7	18.4	13.8	14.6	NS	0.0917
Sour	21.3	23.1	20.2	24.6	20.7	18.5	NS	0.0832
Bitter	14.7	12.3	12.3	15	14	13.7	NS	0.1441
Metallic	11	11	11.2	14.2	13.3	11.2	2.5	**0.0434**
Cabbage water	16.2	15.4	17.6	17.7	17.3	11.3	4.2	**0.0292**
Off	0.7	0.3	0.3	0.3	0.6	4.5	NS	0.1079
Aftertaste								
Overall aftertaste intensity	30.1	30	30.1	30.3	30	29.4	NS	0.9907
Potato	21.1	21.4	22.3	22.2	21.3	20.5	NS	0.8356
Sweet	5.2	6	7.1	5.2	5.5	5.3	NS	0.6304
Metallic	11.8	12.3	10.2	11.7	11.1	9.5	NS	0.2273
Earthiness	10	9.6	11.8	12.1	9.6	9.6	NS	0.1393
Sourness	20.6	19.3	18.3	21.8	22.1	18.5	NS	0.1782
Bitter	15.8	13.1	14.8	16.2	15	13.4	NS	0.1033
Afterfeel								
Astringent	31.2	31.5	30.5	30.4	31.6	30.3	NS	0.9449
Mouthcoating	28	30.2	25.3	28	27.4	27.5	NS	0.5887
Irritant	7.1	5.2	5	6	6.2	5.8	NS	0.2812

LSD = Least Significant Differences, products with a difference in mean score higher then the LSD are significantly different in the represented attribute at the 5% significance level.

NS = No significance difference at 95% confidence level

TABLE A24: MARIS PIPER POTATO PROFILING (1)

	Untreated			Treated				
	Ambient	1.5	4.5	Ambient	1.5	4.5	LSD	p value
Aroma								
Overall aroma intensity	40.3	40.5	41.3	43.8	42.4	42.1	NS	0.4085
Potato	29.5	31.0	30.4	32.0	32.0	30.9	NS	0.6930
Fishy	2.8	1.0	1.5	2.2	2.0	3.1	NS	0.4850
Savoury	1.0	0.6	0.8	0.8	0.5	1.2	NS	0.9534
Earthy	14.2	18.0	17.7	17.1	17.1	13.9	NS	0.2999
Cabbage water	19.5	15.3	18.7	16.4	17.6	18.9	NS	0.4692
Off	0.1	0.1	0.9	0.1	0.1	0.1	NS	0.1246
Appearance								
Colour	43.4	45.4	41.2	46.1	43.3	44.9	NS	0.1227
Smooth	66.6	67.4	65.0	65.7	67.8	66.7	NS	0.9059
Dry	27.3	26.0	29.2	26.0	25.6	25.6	NS	0.4845
Blemishes	4.3	6.5	4.4	3.6	4.3	3.7	NS	0.2250
Glassiness	23.2	24.4	23.4	26.1	24.4	26.4	NS	0.2710
Blackening / Greying	5.5	7.8	7.7	3.6	3.4	3.0	4.0	**0.0481**
Mottled	8.9	6.3	7.0	6.9	8.3	5.8	NS	0.4197
Surface Disintegrating	10.3	7.2	10.0	9.3	6.9	6.7	NS	0.1311
Cut the potato into 2								
Hardness on 1st Cut	30.7	32.7	35.3	31.1	30.9	29.1	NS	0.1366
Texture								
Hardness on 1st bite	21.3	20.1	21.4	21.4	19.5	18.5	NS	0.6651
Absorbent	45.7	47.5	46.7	40.2	42.8	43.9	NS	0.1479
Waxy	18.0	18.5	23.8	23.0	20.3	20.9	NS	0.4848
Floury	35.7	39.0	34.3	27.3	33.0	31.6	NS	0.0770
Cloying	37.1	39.3	39.0	35.3	32.2	34.0	4.7	**0.0193**
Grainy	19.0	21.5	19.6	19.8	18.8	15.6	NS	0.2636
Breakdown rate	43.1	42.5	42.1	46.9	47.0	50.1	4.1	**0.0007**
Flavour								
Overall flavour intensity	39.0	40.9	39.4	40.3	39.9	41.7	NS	0.6439
Potato	31.2	31.9	31.4	32.8	31.4	32.8	NS	0.8591
Sweet	14.8	16.0	18.9	19.3	17.6	19.6	NS	0.2997
Fishy	0.5	0.4	0.1	0.3	0.1	0.3	NS	0.5867
Savoury	0.7	0.4	0.4	0.4	0.4	0.9	NS	0.7265
Earthy	14.8	15.6	13.5	14.9	14.5	13.1	NS	0.7416
Sour	13.4	11.8	12.8	11.8	13.6	13.3	NS	0.8030
Bitter	6.9	8.9	10.5	9.6	8.5	9.3	NS	0.2076
Metallic	5.8	5.9	7.0	6.4	5.3	6.5	NS	0.6911
Cabbage water	14.8	13.7	13.8	11.9	15.4	18.5	3.9	**0.0381**
Off	0.0	0.1	0.4	0.1	0.4	0.1	NS	0.4109
Aftertaste								
Overall aftertaste intensity	28.5	30.7	31.1	31.0	30.0	32.3	NS	0.1535
Potato	21.8	24.3	22.3	22.1	22.4	23.3	NS	0.5017
Sweet	12.4	11.4	13.5	14.7	12.5	17.4	4.5	**0.0098**
Metallic	5.5	7.2	7.4	8.3	6.3	6.3	NS	0.1878
Earthiness	8.9	10.5	8.6	9.1	8.5	8.5	NS	0.6451
Sourness	13.6	13.9	13.2	12.9	14.2	13.5	NS	0.9689
Bitter	8.6	10.2	11.3	10.6	9.3	11.2	NS	0.4756
Afterfeel								
Astringent	33.6	34.3	37.0	34.0	34.4	32.3	NS	0.0638
Mouthcoating	26.7	26.3	28.2	25.0	24.9	23.8	NS	0.1611
Irritant	4.1	3.3	5.9	4.3	4.2	4.5	NS	0.1890

LSD = Least Significant Differences, products with a difference in mean score higher then the LSD are significantly different in the represented attribute at the 5% significance level.

NS = No significance difference at 95% confidence level

TABLE A25: ESTIMA POTATO PROFILING (2)

	Untreated			Treated				
	Ambient	**1.5**	**4.5**	**Ambient**	**1.5**	**4.5**	**LSD**	**P Value**
Aroma								
Overall aroma intensity	40.8	41.3	42.4	40.8	38.6	38.1	NS	0.2335
Potato	25.1	27.1	27.6	26.1	27.7	26.1	NS	0.7508
Fishy	2.1	1.9	4.8	3.0	2.2	2.4	NS	0.3254
Savoury	1.0	0.4	0.1	0.1	0.1	0.1	NS	0.4718
Earthy	9.6	13.7	13.4	10.1	12.9	11.2	NS	0.2184
Cabbage water	19.8	23.1	20.3	22.1	21.0	19.3	NS	0.6697
Off	2.7	1.9	0.4	1.8	0.0	0.1	NS	0.4581
Appearance								
Colour	46.2	53.7	52.9	53.3	49.4	52.2	4.6	**0.0106**
Smooth	74.4	72.9	71.2	69.8	72.1	74.8	NS	0.1653
Dry	26.7	26.5	24.2	27.2	24.7	25.6	NS	0.8748
Blemishes	2.6	3.8	3.1	8.7	5.4	7.5	3.2	**0.0008**
Glassiness	18.6	20.9	19.1	19.8	19.8	17.6	NS	0.1589
Blackening/Greying	1.2	3.1	3.8	5.3	4.1	2.6	NS	0.1571
Mottled	2.0	4.6	4.8	4.1	4.3	3.2	NS	0.1350
Surface Disintegrating	3.2	4.2	4.2	5.6	3.0	4.0	NS	0.5565
Cut the potato into 2								
Hardness on 1st Cut	20.5	23.6	24.5	24.4	26.1	26.6	3.6	**0.0201**
Texture								
Hardness on 1st bite	14.4	17.1	15.2	17.3	17.7	16.1	NS	0.4905
Absorbent	34.2	32.5	34.2	37.1	34.3	35.9	NS	0.7555
Waxy	25.9	25.3	22.5	24.8	27.0	25.4	NS	0.7071
Floury	20.8	24.8	24.5	27.1	24.0	27.8	NS	0.4519
Cloying	28.1	29.4	29.9	31.4	28.7	31.7	NS	0.5707
Grainy	14.3	16.3	17.3	21.8	18.0	19.6	NS	0.0572
Breakdown rate	51.4	51.3	49.7	47.2	46.5	46.3	NS	0.1403
Flavour								
Overall flavour intensity	41.3	37.4	39.5	41.0	36.2	39.7	NS	0.1098
Potato	27.2	24.8	27.2	27.9	27.6	28.3	NS	0.4393
Sweet	21.1	19.8	18.8	19.2	21.5	25.4	NS	0.1701
Fishy	0.5	0.1	0.7	0.7	0.2	0.1	NS	0.6342
Savoury	0.2	0.3	0.0	0.4	0.3	0.1	NS	0.4895
Earthy	12.2	12.4	11.4	12.8	11.9	12.7	NS	0.9628
Sour	19.0	14.3	15.7	16.3	13.9	13.5	NS	0.1644
Bitter	13.5	9.7	11.4	12.6	8.6	8.7	NS	0.0985
Metallic	10.6	9.0	8.5	9.9	7.5	7.1	NS	0.3569
Cabbage water	18.4	15.5	15.9	18.7	18.0	17.9	NS	0.3770
Off	0.1	2.1	1.2	1.6	0.1	0.5	NS	0.1160
Aftertaste								
Overall aftertaste intensity	30.9	28.2	28.2	30.8	27.9	28.7	NS	0.1710
Potato	18.9	16.7	18.2	17.8	18.3	18.2	NS	0.7941
Sweet	14.5	13.6	12.1	12.2	15.8	18.7	4.5	**0.0375**
Metallic	9.4	8.3	9.4	10.5	6.7	6.0	2.4	**0.0023**
Earthiness	8.8	8.4	8.0	7.4	8.2	7.8	NS	0.9172
Sourness	20.3	16.1	17.6	18.4	16.1	14.7	NS	0.0968
Bitter	13.9	13.3	13.5	15.8	12.8	10.8	NS	0.1177
Afterfeel								
Astringent	31.1	32.4	31.4	34.2	32.6	32.9	NS	0.4318
Mouthcoating	20.0	20.2	21.0	25.0	23.9	23.8	3.4	**0.0121**
Irritant	5.1	6.5	5.0	5.1	4.5	4.8	NS	0.7186

LSD = Least Significant Differences, products with a difference in mean score higher then the LSD are significantly different in the represented attribute at the 5% significance level.
NS = No significance difference at 95% confidence level

TABLE A26: MARFONA POTATO PROFILING (2)

	Untreated			Treated				
	Ambient	1.5	4.5	Ambient	1.5	4.5	LSD	P Value
Aroma								
Overall aroma intensity	35.8	34.3	33.8	34.3	35.0	35.8	NS	0.7629
Potato	26.7	25.2	26.0	25.0	25.4	25.7	NS	0.9510
Fishy	3.1	3.3	2.2	3.8	1.4	3.3	NS	0.4753
Savoury	0.1	0.8	0.1	0.1	0.3	0.1	NS	0.1239
Earthy	14.6	11.2	14.5	12.8	14.5	10.7	NS	0.0717
Cabbage water	16.1	12.7	14.9	15.4	13.4	14.9	NS	0.5140
Off	0.0	0.1	0.1	0.1	1.3	0.1	NS	0.1407
Appearance								
Colour	33.6	33.0	37.0	33.5	36.4	34.4	NS	0.0919
Smooth	50.9	48.8	46.5	45.1	45.4	54.3	NS	0.0694
Dry	37.3	39.8	42.8	40.9	43.9	39.7	NS	0.2707
Blemishes	5.0	3.3	6.9	2.8	5.9	3.9	NS	0.0728
Glassiness	18.4	19.6	22.0	18.4	20.3	20.1	NS	0.5469
Blackening/Greying	2.6	2.9	4.0	1.6	4.6	2.8	NS	0.3635
Mottled	9.3	13.4	12.8	12.9	17.3	13.1	NS	0.2364
Surface Disintegrating	24.7	30.8	32.3	34.4	32.9	25.1	NS	0.0875
Cut the potato into 2								
Hardness on 1st Cut	31.0	30.2	31.6	25.8	28.6	29.7	NS	0.0682
Texture								
Hardness on 1st bite	17.4	15.1	17.9	14.2	13.4	16.2	NS	0.0945
Absorbent	49.7	53.1	54.2	51.3	53.4	51.7	NS	0.4589
Waxy	8.0	4.3	5.2	5.4	6.7	6.7	NS	0.6777
Floury	51.5	53.1	55.3	54.0	53.7	51.9	NS	0.8237
Cloying	40.6	45.9	44.4	44.9	46.7	41.3	NS	0.0982
Grainy	24.0	25.9	22.8	21.7	23.7	24.2	NS	0.4986
Breakdown rate	43.7	43.5	42.7	43.4	41.4	43.2	NS	0.8531
Flavour								
Overall flavour intensity	37.1	35.6	34.3	34.9	35.2	36.6	NS	0.4276
Potato	29.0	28.3	28.8	27.8	26.4	27.9	NS	0.5412
Sweet	5.5	4.8	6.1	6.7	9.1	5.6	NS	0.0511
Fishy	0.1	0.1	0.1	0.0	0.0	0.6	NS	0.0699
Savoury	0.5	0.6	0.3	0.4	0.3	0.2	NS	0.7470
Earthy	12.9	14.3	14.2	13.8	12.9	12.6	NS	0.9137
Sour	21.8	18.4	18.6	20.5	20.7	18.0	NS	0.2682
Bitter	13.6	13.9	12.9	14.1	14.1	12.2	NS	0.8473
Metallic	9.5	8.6	7.5	10.5	9.1	8.2	NS	0.5346
Cabbage water	12.0	10.6	9.9	13.3	11.5	9.1	NS	0.2772
Off	0.6	0.5	1.1	0.0	1.0	0.1	NS	0.2752
Aftertaste								
Overall aftertaste intensity	29.8	27.3	28.4	29.0	30.4	28.7	NS	0.2475
Potato	20.5	20.0	20.4	21.1	19.5	19.3	NS	0.8327
Sweet	2.7	2.4	3.5	2.8	4.5	3.8	NS	0.5036
Metallic	9.0	8.0	8.1	9.4	9.5	8.6	NS	0.8329
Earthiness	9.6	9.9	10.4	10.3	9.8	9.8	NS	0.9935
Sourness	20.3	17.2	18.1	21.9	20.3	18.3	NS	0.2170
Bitter	15.7	12.6	12.8	14.4	14.5	13.3	NS	0.4277
Afterfeel								
Astringent	36.6	36.6	38.9	36.9	38.9	35.6	NS	0.1887
Mouthcoating	32.1	32.0	31.2	31.4	32.8	29.9	NS	0.6954
Irritant	7.1	6.8	4.9	6.1	8.0	8.2	NS	0.0750

LSD = Least Significant Differences, products with a difference in mean score higher then the LSD are significantly different in the represented attribute at the 5% significance level.

NS = No significance difference at 95% confidence level

TABLE A27: MARIS PIPER POTATO PROFILING (2)

10.1.9.1. Aroma

Assessors evaluated a total of 7 attributes for the aroma category (Tables A22 to A27). A significant difference was found only on the first assessment for 2009 for Estima on the earthy aroma.

10.1.9.1.1. Overall aroma intensity:

The overall aroma intensity was non-significant across each variety and treatment condition. Assessors indicated a moderate intensity for this attribute. For treated potatoes, an increase in CO_2, generally showed a decrease of overall aroma intensity, except for Maris Piper at 2nd assessment, which showed an increase in overall flavour with the increase of CO_2.

10.1.9.1.2. Potato

No significant difference was identified between each variety and treatment condition.

10.1.9.1.3. Fishy / Savoury

No trends were observed between varieties and treatment conditions. Across the samples this aroma character was either not apparent or appeared to be present at low levels.

10.1.9.1.4. Earthy

With the exception of the first assessment: Untreated Estima tubers (Table 4), no trends were observed within the other varieties and treatment conditions. A significant difference was seen between the ambient and the 1.5% CO_2 sample, with the ambient tuber being significantly earthier in aroma (both using Fisher LSD and Tukey's HSD). A graphical display of this attribute is shown in figure A41 below.

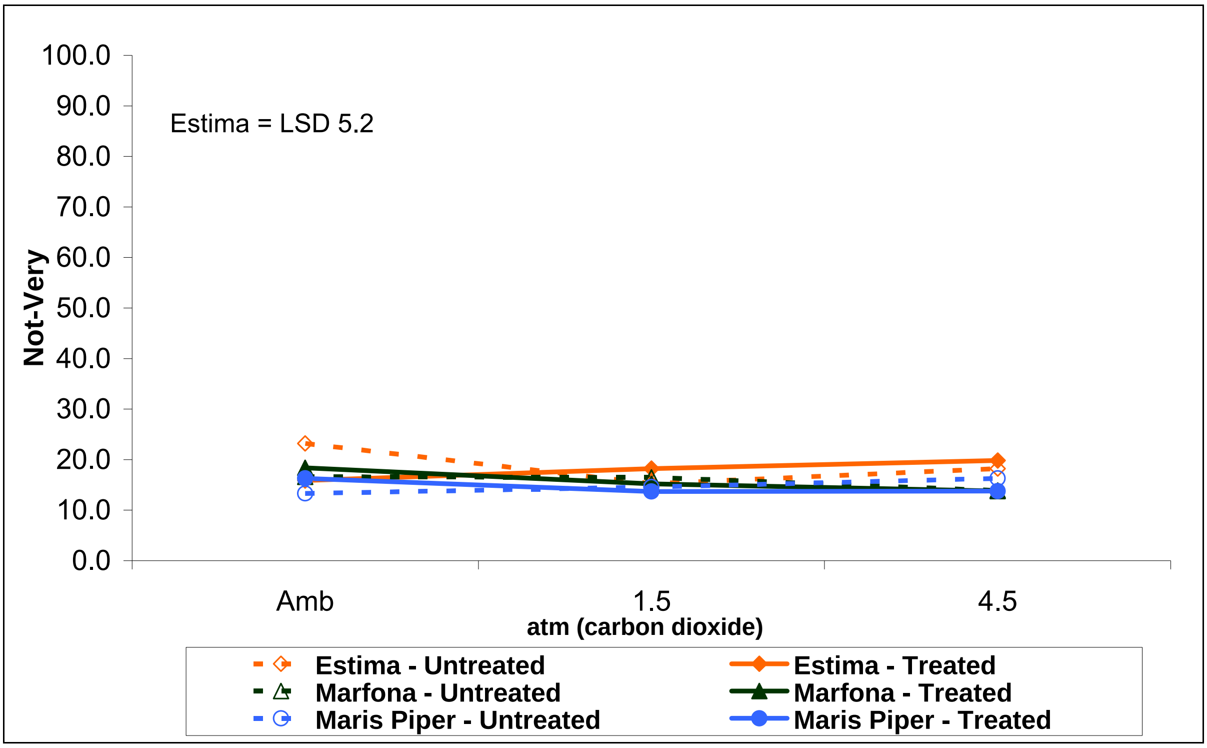


FIGURE A41. EARTHY AROMA – ASSESSMENT 1

10.1.9.1.5. Cabbage water

No trends were observed within the varieties and the treatment conditions. Examination of the means scores indicated that the Maris Piper tested in the second assessment period was perceived as having the least cabbage water aroma.

10.1.9.1.6. Off

No trends were observed within varieties and treatment conditions. Across the samples the off aroma character was either not apparent or appeared at low levels.

10.1.9.2. Appearance

The Appearance category consisted of eight attributes, of which six attributes were significant (Tables 4 to 9). Four of the significant attributes displayed related to samples in assessment 1. These were *smooth, blackening/ greying, mottled* and *dry*. In assessment 2 there were three significant attributes - *colour, blemishes* and *blackening/ greying.* The attributes *glassiness* and *surface disintegration* were found to be non significant across all varieties and treatments.

10.1.9.2.1. Colour

Colour was significant in only the Marfona variety during the second assessment period, for the untreated tubers (table A26). Both the 1.5% CO_2 and 4.5% CO_2 untreated tubers were significantly darker in colour compared to the ambient untreated tuber as shown in Figure A42 (dotted dark green line). Of all the tubers assessed the Marfona appeared to be the darkest, with samples tested in the first assessment perceived as being darker than those assessed in the second assessment period. The Maris Piper emerged as being the lightest of the three tuber varieties (figure A42).

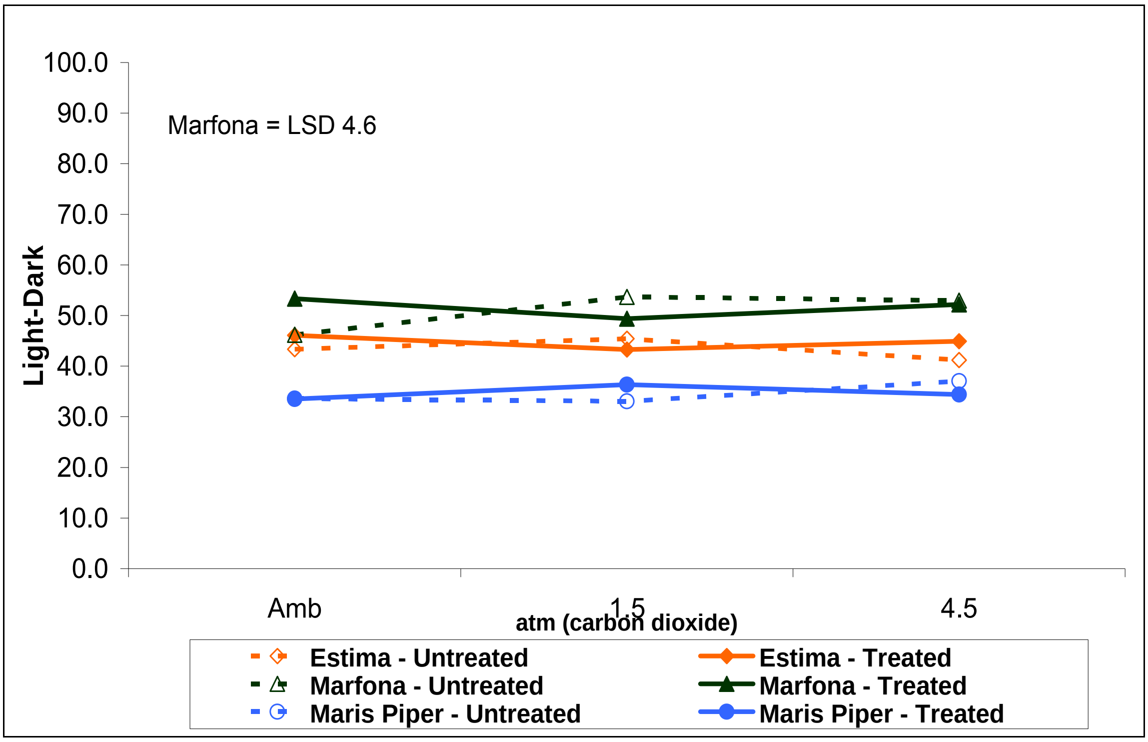


FIGURE A42. COLOUR INTENSITY – ASSESSMENT 2

10.1.9.2.2. Smooth appearance

A significant difference was identified only in assessment 1 for the Estima tuber. The untreated ambient Estima tuber was identified as the smoothest Estima tuber and was significantly smoother than the untreated 1.5% CO_2 Estima tubers. None of the treated Estima tubers were significantly different to each other, however the ambient and the 4.5% CO_2 treated Estima tubers were less smooth in appearance than the untreated ambient tuber. A graphical display of the smooth appearance of tubers tested in assessment 1 is shown in Figure A43.

In general the Marfona variety was the smoothest potato, especially the samples tested in the second assessment. The Maris Piper potatoes were the least smooth of all the varieties, with those in the first evaluation being considered less smooth compared to those in the second assessment.

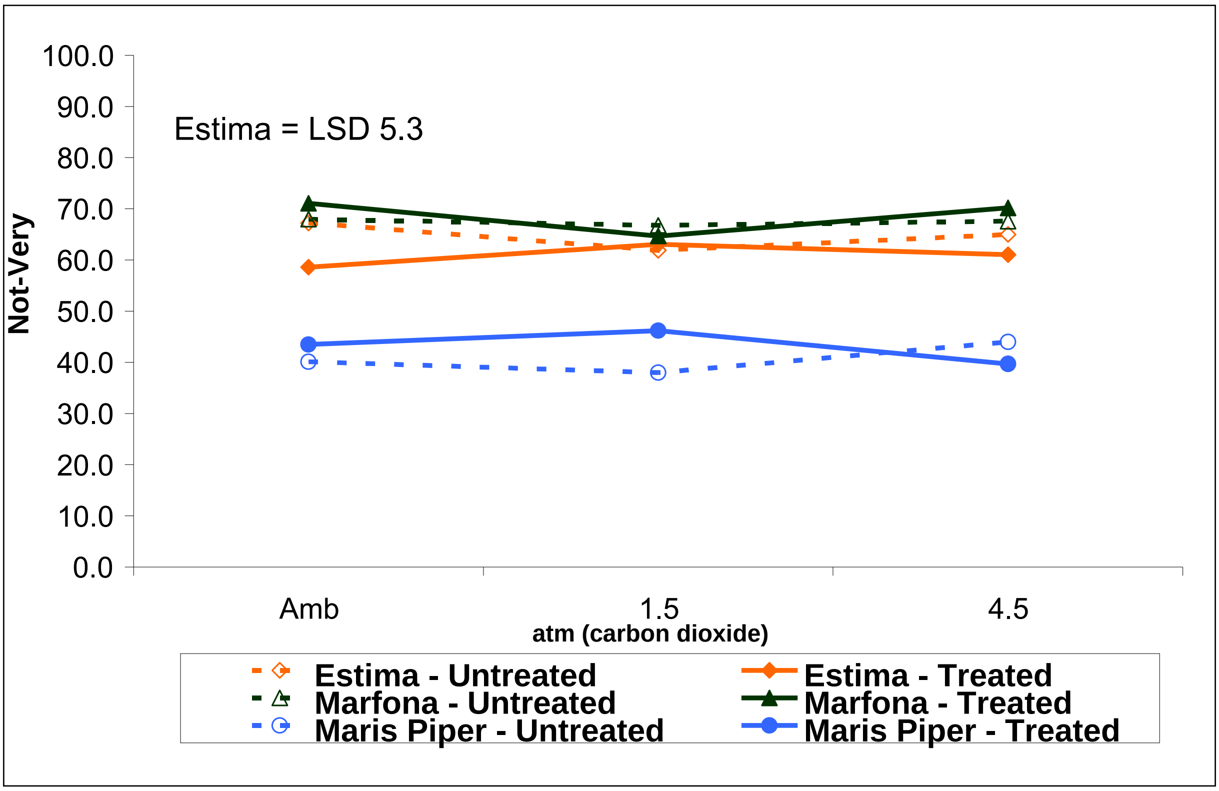


FIGURE A43. SMOOTH APPEARANCE – ASSESSMENT 1

10.1.9.2.3. Dry appearance

Dry appearance was significant for the Maris Piper tuber profiled during the first assessment. Results for the untreated Maris Piper tubers indicated that neither the 1.5% CO_2 nor the 4.5% CO_2 tubers were significantly different from the ambient; however there was a significant difference between these two treatments, with the 1.5% CO_2 tuber significantly dryer in appearance than the 4.5% CO_2 as shown in Figure A44 (blue dotted line).

For the treated Maris Piper tubers, there was no significant difference between the three tubers.

A further significant difference was seen at the treated and untreated tubers at 1.5% CO_2. Here the untreated tuber had a drier appearance than the treated tuber.

Generally the Maris Piper tubers were the most dry of all the varieties and the Marfona evaluation in the first assessment least dry.

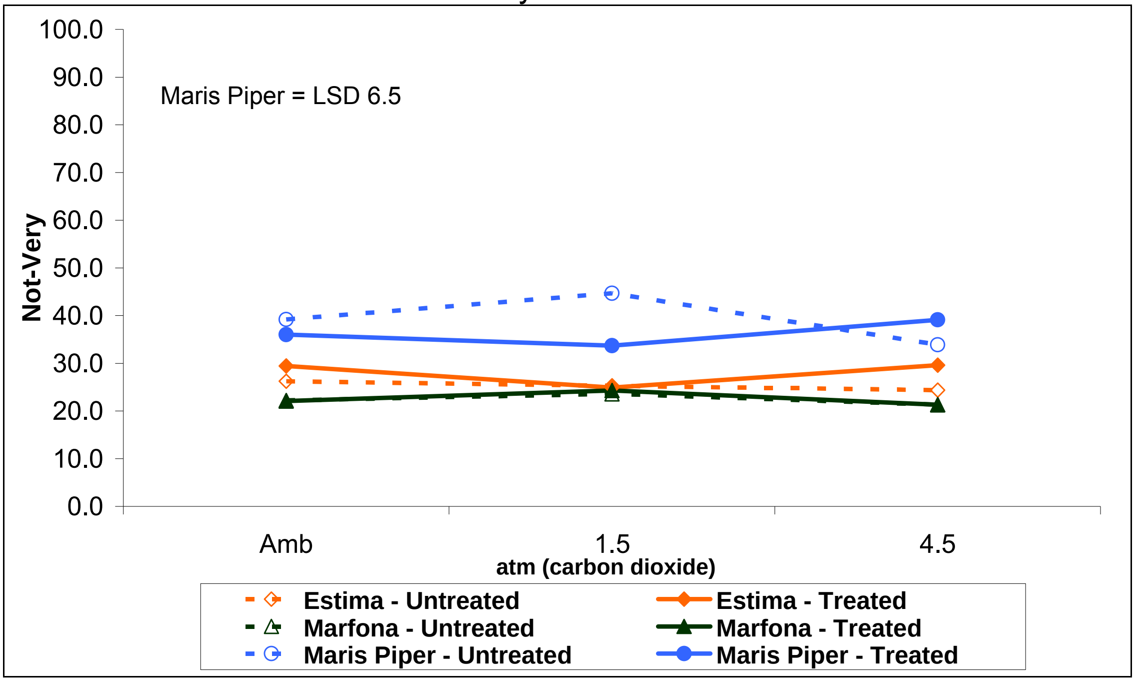


FIGURE A44. DRY APPEARANCE – ASSESSMENT 1

10.1.9.2.4. Blemishes

Blemishes were found only at very low to levels on all the tuber samples, however a significant difference was found on the Marfona tubers in assessment 2. There was a significant difference between the 1.5 and the ambient treated tubers, with –although still at only very minor level - the ambient tuber having a larger amount of *blemishes* present. This significant difference was not seen for the untreated samples. A graphical display on the low levels of blemishes seen at the second assessment is shown in Figure A45.

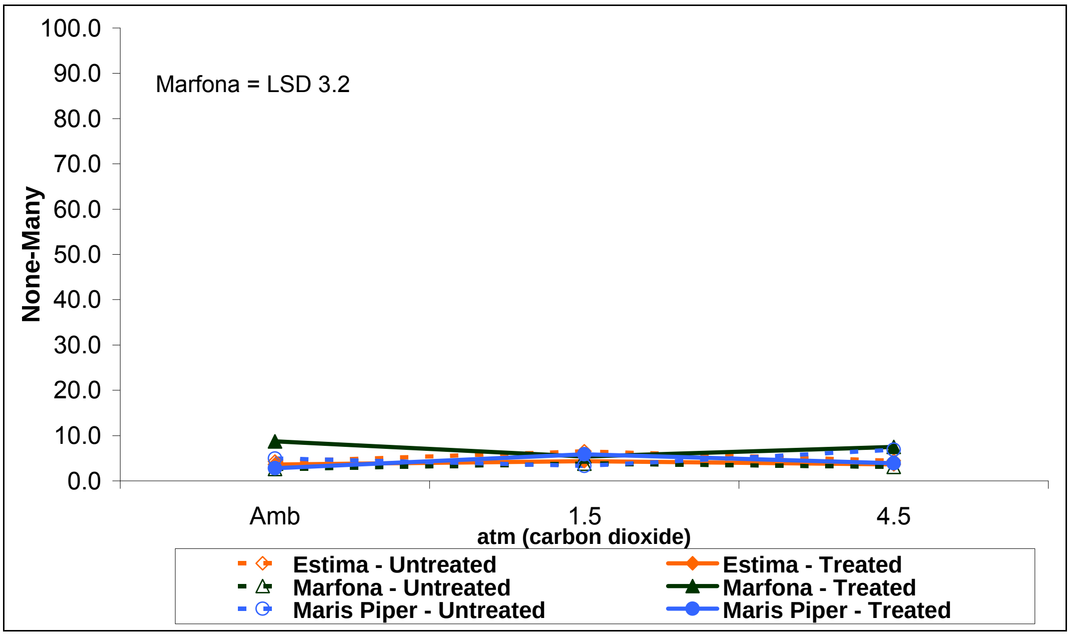


FIGURE A45. BLEMISHES – ASSESSMENT 2

10.1.9.2.5. Glassiness:

Some glassiness was present in all of the samples, no real trend however could be identified based on variety, storage condition or carbon dioxide level. What was detected was that the level of perceived glassiness decreased in all varieties during the second assessment. In general the Estima potatoes were found to be the glassiest.

10.1.9.2.6. Blackening / greying:

Only very minor levels of blackening/ greying were perceived. Estima tubers at both assessments and Marfona at the first assessment showed a significant difference between the tuber samples within their respective sets. No clear trend, however, was apparent by storage condition or carbon dioxide level.

- In the first Estima assessment, untreated 1.5% CO_2 and treated 4.5% CO_2 samples were most blackened/greyed (orange lines, Figure A46)
- During the second Estima assessment, untreated 1.5% and untreated 4.5% CO_2 Estima tubers were more blackened/greyed than their treated equivalents (orange lines Figure A47)
- The opposite was seen in the first Marfona assessment, whereby the untreated 1.5% and untreated 4.5% CO_2 Marfona tubers were less black/grey than the treated 1.5% and treated 4.5% CO_2 Marfona tubers (dark green lines figure 6)
-

Even though these significant differences were identified using Fisher LSD, only very low levels were found. Moreover, Tukey's HSD only showed a significant difference for the Estima tubers at first assessment.

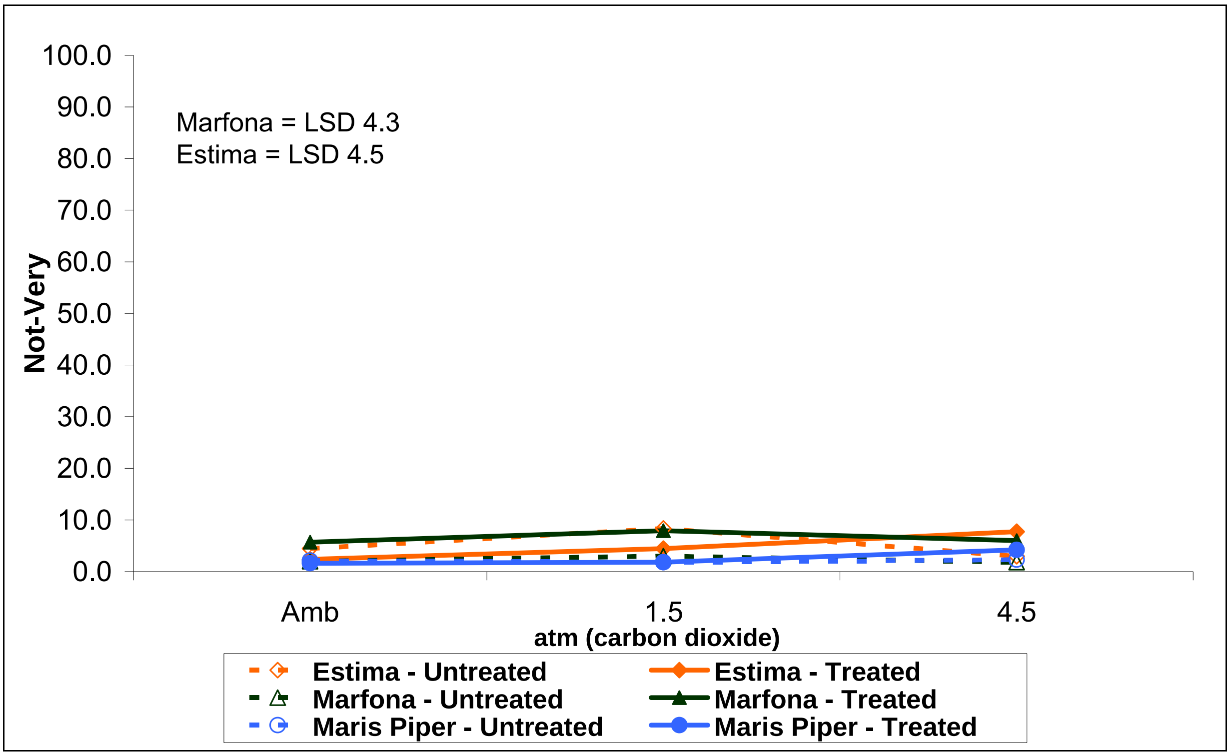


FIGURE A46. BLACKENING / GREYING – ASSESSMENT 1

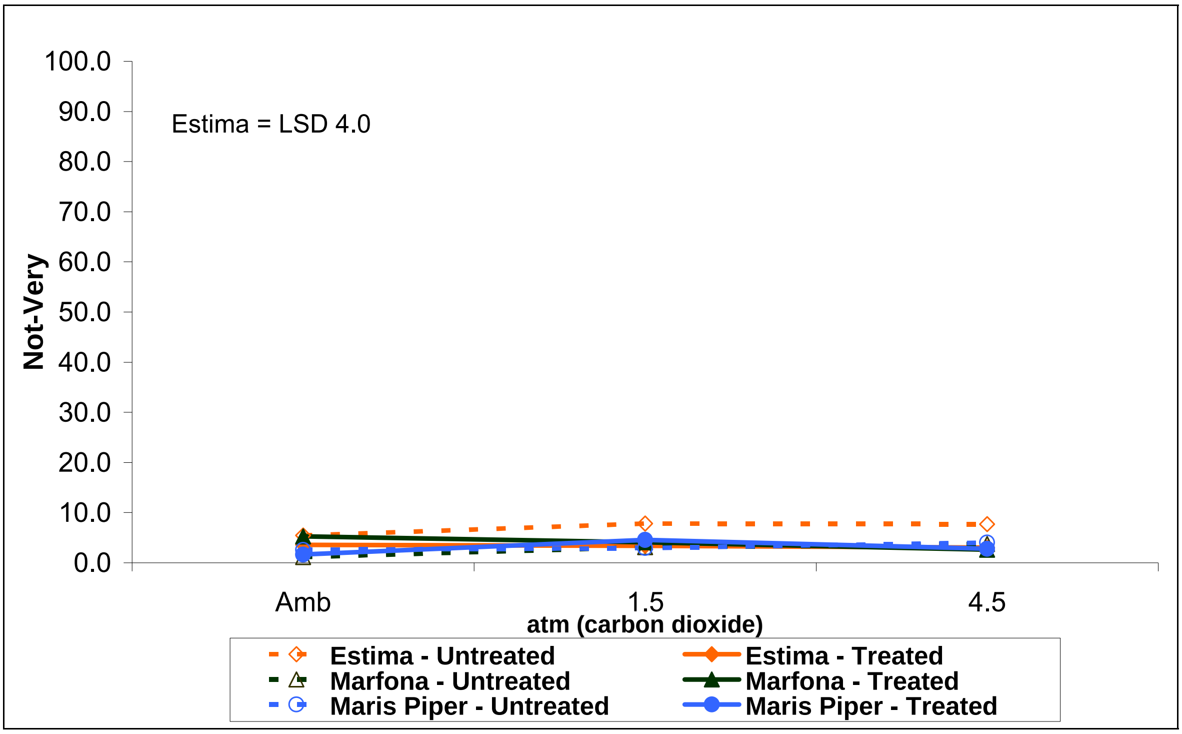


FIGURE A47, BLACKENING / GREYING – ASSESSMENT 2

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10.1.9.2.7. Mottled appearance:

Very low levels of mottling was perceived, with the highest (but very slight) levels in the Maris Piper tubers.
The mottled attribute was significantly different in the Marfona tubers tested in assessment 1, with the 1.5% CO_2 tuber significantly more mottled compared to the ambient treated and all untreated tubers (Figure A48).

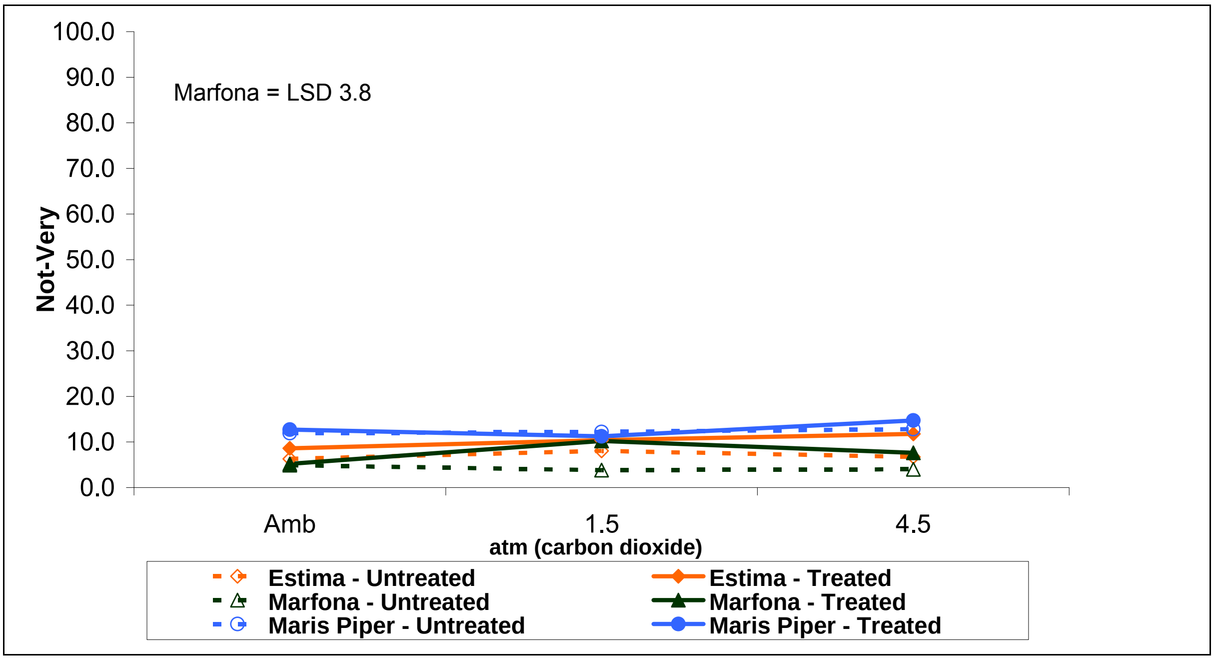


FIGURE A48. MOTTLED APPEARANCE – ASSESSMENT 1

10.1.9.2.8. Disintegrating surface

Although all tubers were perceived to have varying levels of disintegrating surface, none differed significantly.
Maris Piper was identified to disintegrate most. The surface of Marfona potatoes did not really disintegrate at all, similarly ethylene treated Estima potatoes disintegrated only very slightly.

10.1.9.3. Texture/ Mouthfeel

A total of 8 attributes were evaluated by the panel. Of these, 7 attributes were found to significantly differentiate the samples. The 6 attributes which were significant in assessment 1 were: *hardness on 1st cut, hardness on 1st bite, waxy, floury, cloying, grainy* and *breakdown rate*. Three attributes were found to be significant in assessment 2. They were: *hardness on 1st cut, cloying* and *breakdown rate*.

10.1.9.3.1. Hardness on 1st cut

Assessors were asked to cut the potato sample into two pieces.

All tubers were relatively soft on first cut. The Marfona samples showed a significant difference in both assessments.
For both assessments, the treated Marfona tubers exposed to 1.5% and 4.5% CO_2 were (numerically) harder, as shown in Figures A49 and A50 in dark green.

Overall the Marfona tubers in the second assessment period were softest on first cut. The Treated Estima tubers showed a decrease in hardness on first cut with the increase of CO_2.

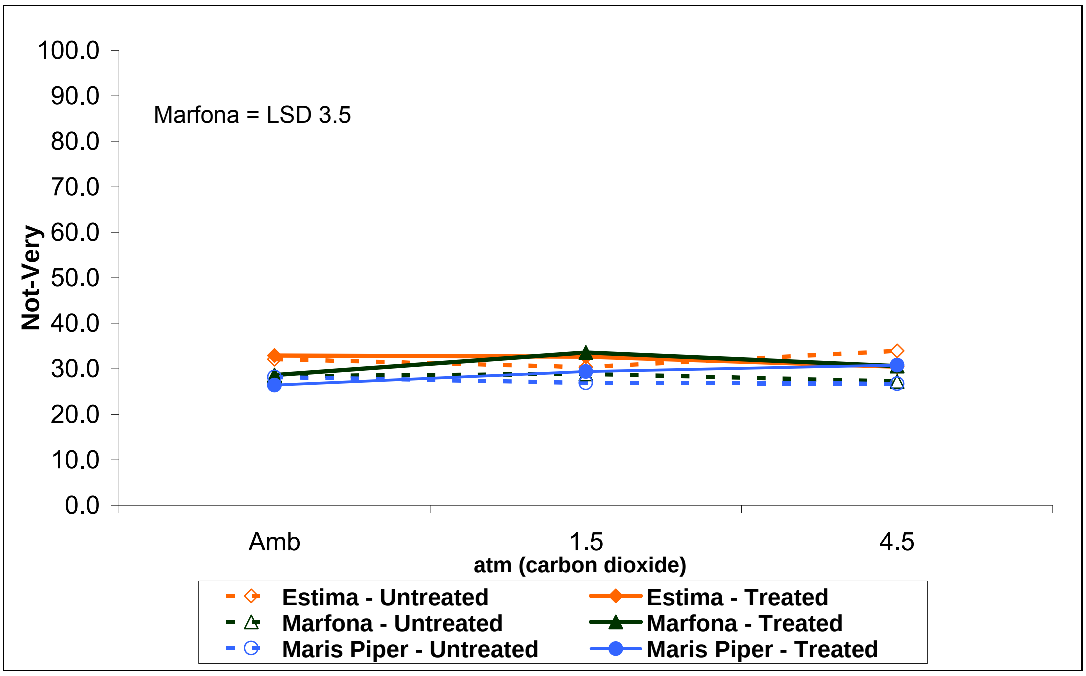


FIGURE A49. HARDNESS ON FIRST CUT – ASSESSMENT 1

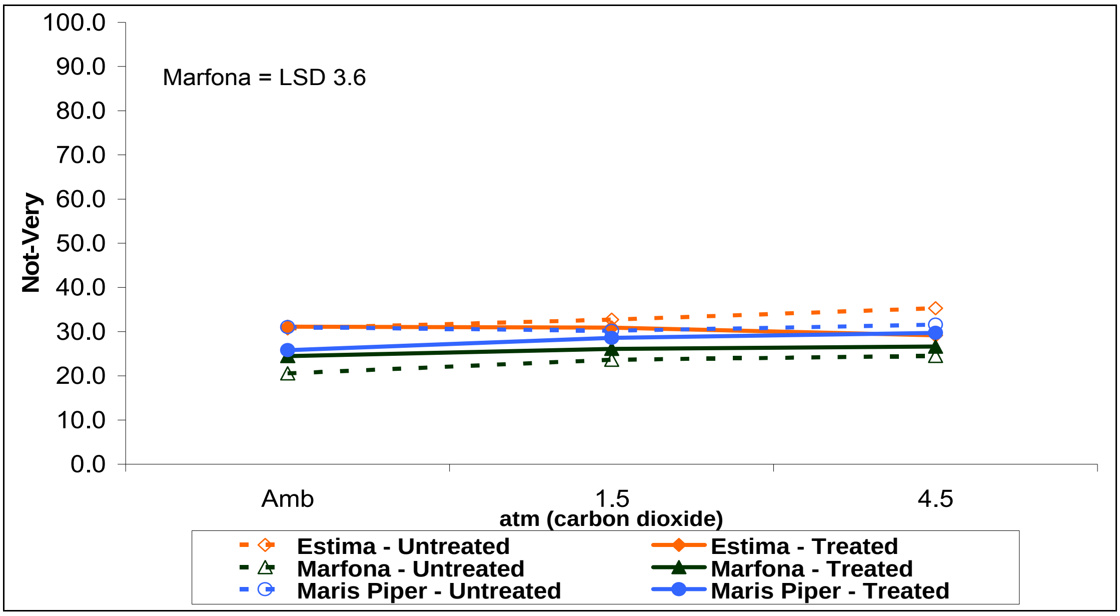


FIGURE A50. HARDNESS ON FIRST CUT – ASSESSMENT 2

10.1.9.3.2. Hardness on 1st bite

All samples were relatively soft on first bite. Only the Marfona and Maris Piper tubers evaluated in assessment 1 showed a significant difference (no significant differences were seen in assessment 2). No clear trend on the source of the significant difference was seen. A graphical display of the hardness on first bite of assessment 1 is shown in Figure A51.

The Estima was hardest on first bite and treated Estima tubers showed a very slight decrease in hardness on first bite with the increase of CO_2.

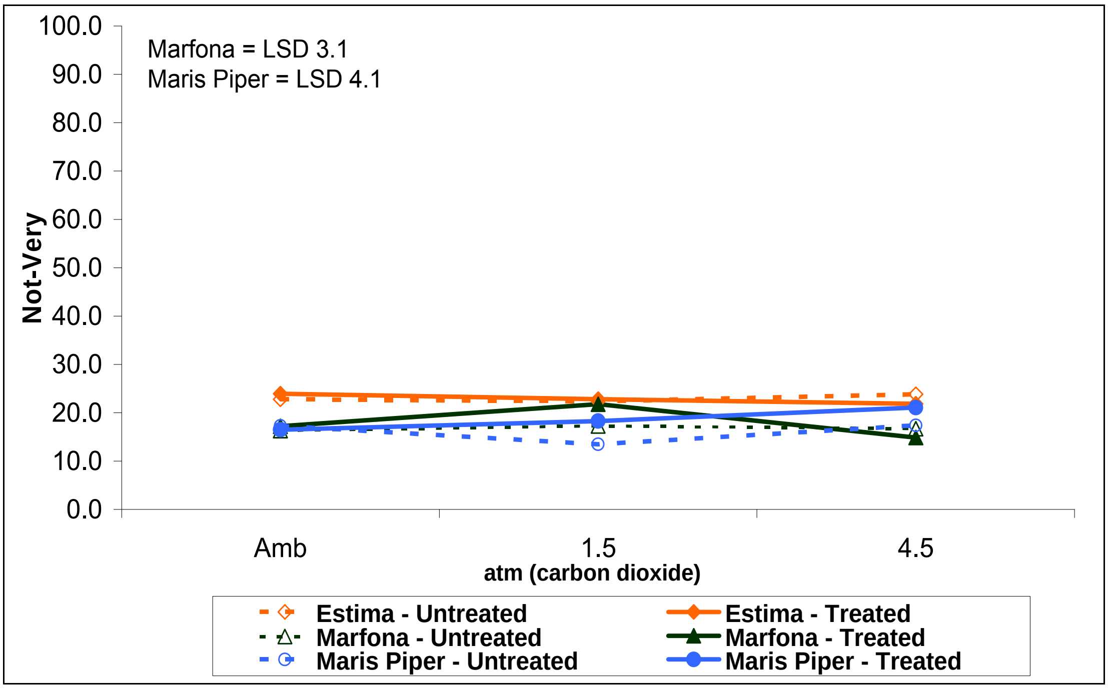


FIGURE A51. HARDNESS ON FIRST BITE – ASSESSMENT 1

10.1.9.3.3. Absorbent

Although there were varying degrees of absorbency detected by the trained panel, none of the potato samples showed any significant differences between treatments. Closer examination of the results indicated that the Marfona was the least absorbent, compared to the Maris Pipers, which were the most absorbent, with the first assessment more absorbent than the second.

10.1.9.3.4. Waxy

All tuber samples exhibited a degree of waxiness, with the Maris Piper tubers displaying the least compared to the Marfona tubers which were most waxy.
The Marfona and Estima tubers in assessment 1 showed significant differences using Fisher LSD. Using Tukey's HSD, only the Marfona tubers in assessment 1 showed a significant difference. No clear trend was observed on the origin of the significant differences identified.
A very slight increase in the level of waxiness could be seen in the treated potatoes evaluated in assessment 1 as the CO_2 levels increased. A graphical representation of perceived waxiness in assessment 1 is shown in Figure A52.

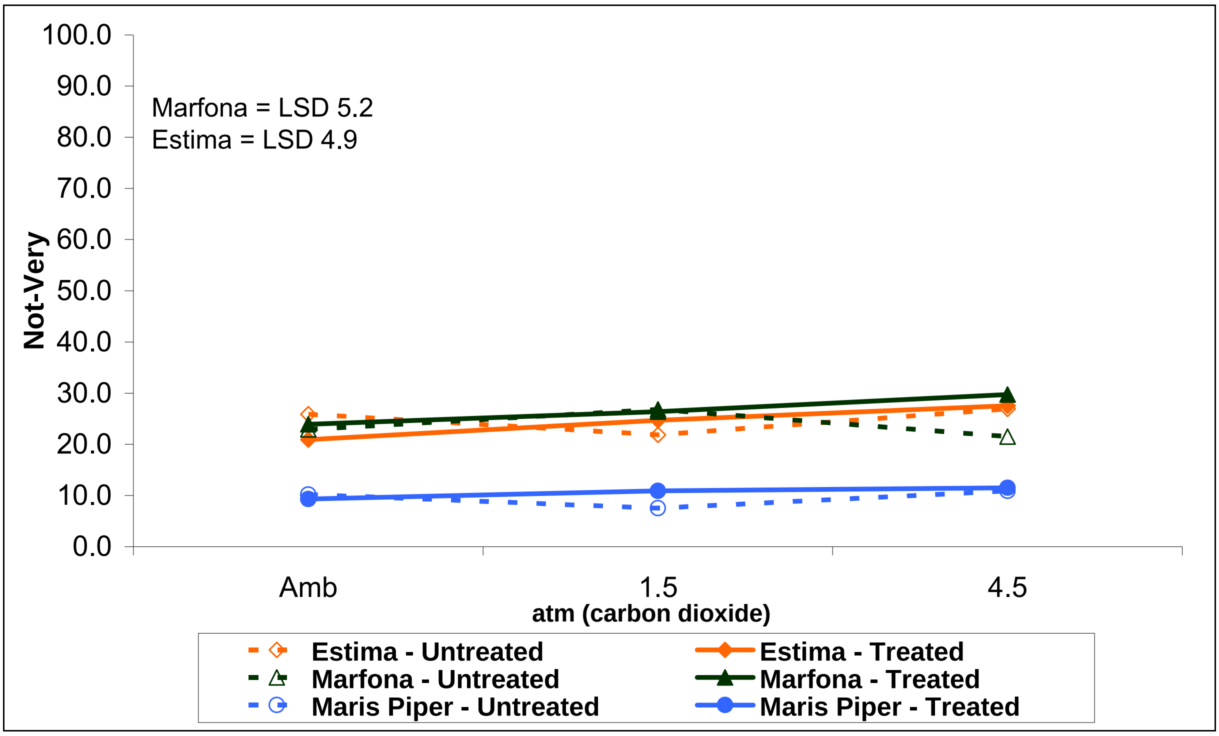


FIGURE A52. WAXY – ASSESSMENT 1

10.1.9.3.5. Floury

All tubers showed a level of perceived flouriness, with the Marfona exhibiting the least flouriness and Maris Piper showing the most flouriness. When comparing the varieties between assessment periods, the tubers in the second assessment were more floury that those in the first.
Marfona and Maris Piper tubers evaluated in the first assessment displayed a statistical significant difference. Marfona tubers in the first assessment appeared to decrease very slightly in floury texture with the increase of CO_2.

The origin of the significant difference for Maris Piper in the first assessment was not clear. A graphical display of flouriness perceived at the first assessment in shown in Figure A53.

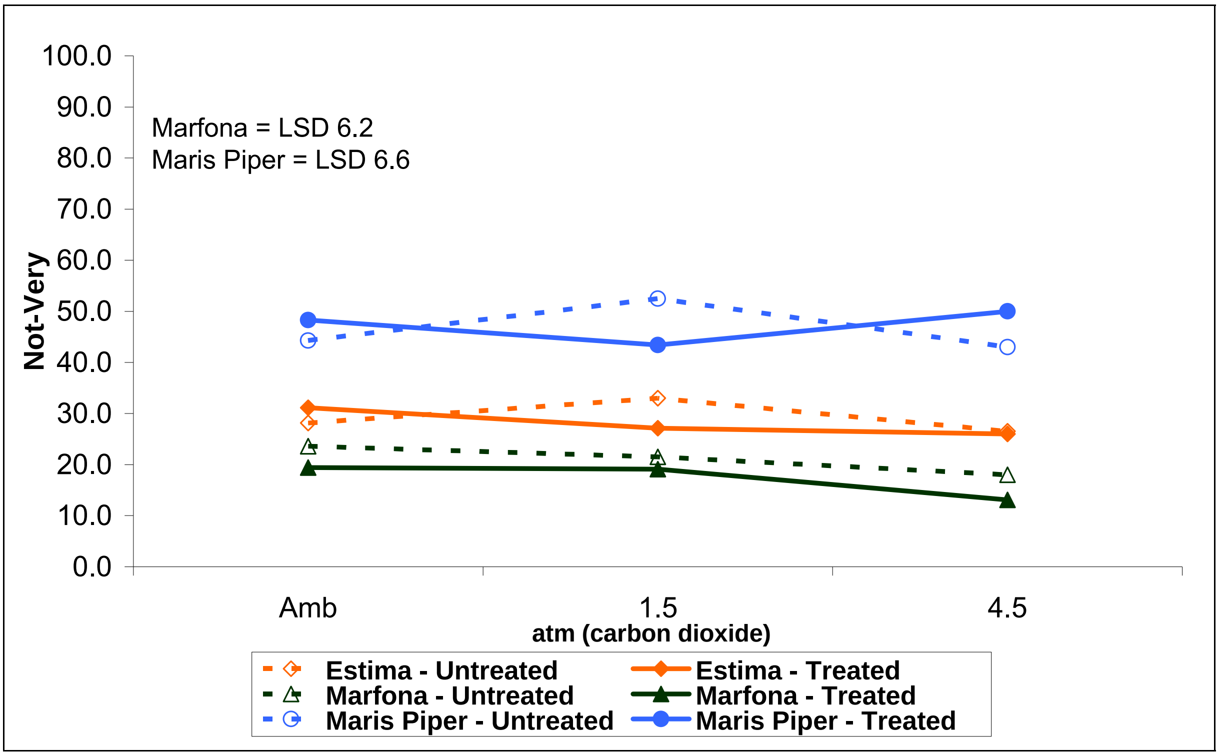


FIGURE A53. FLOURY – ASSESSMENT 1

10.1.9.3.6. Cloying:

The cloying attribute was present in all samples, with the Marfona tubers being the least cloying and the Maris Piper most cloying. A significant difference was seen in two of the varieties tested; Marfona tubers in assessment 1 and the Estima tubers in assessment 2 (Figure A54 and A55).

A significant difference was detected in the Marfona tubers assessment 1, with the ambient stored tubers being numerically slightly more cloying than samples stored under CO_2 conditions and the ambient untreated sample being statistically significantly more cloying than the 1.5%CO_2 untreated Marfona sample.

The other significant difference was seen in the Estima tubers tested in assessment period 2. Slight differences were seen when comparing the treated against the untreated tubers; here both the treated tubers exposed to CO_2 levels at 1.5% and 4.5% were significantly less cloying that those that were untreated.

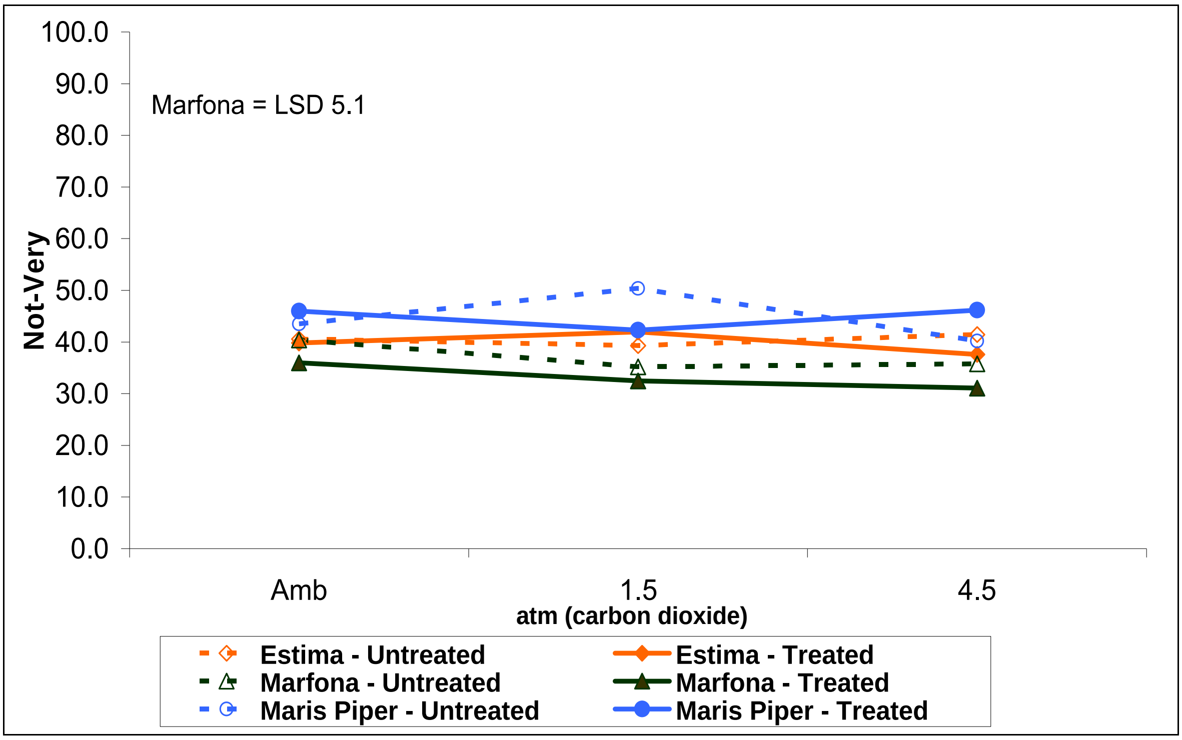


FIGURE A54. CLOYING – ASSESSMENT 1

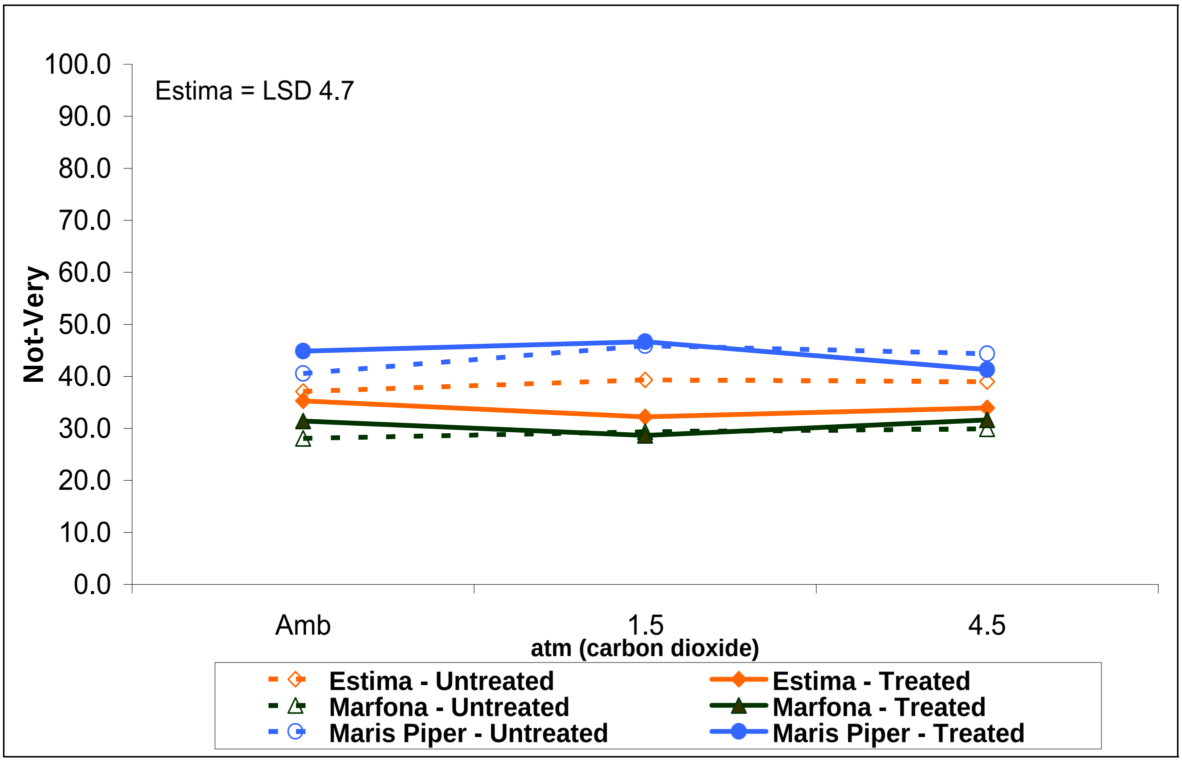


FIGURE A55. CLOYING – ASSESSMENT 2

10.1.9.3.7. Grainy

All tubers showed slight levels of grainy texture, with the Maris Piper in assessment 2, exhibiting the greatest level.
Grainy was significantly different in the Marfona potatoes tested in the first assessment period. In both the treated and untreated potatoes, the potatoes that were

exposed to a level of 4.5% CO_2 were less grainy than those that were exposed to 1.5% CO_2, and bringing them to a similar level to the ambient samples, as shown in Figure 16.

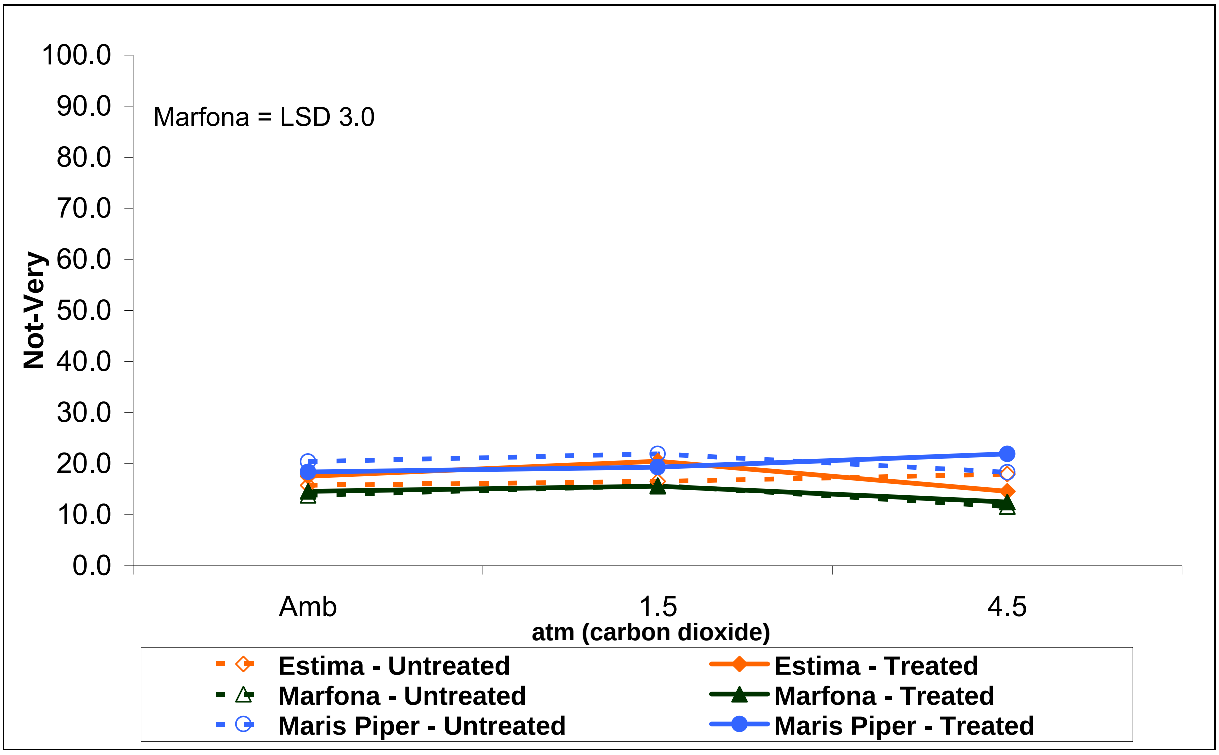


FIGURE 16. GRAINY – ASSESSMENT 1

10.1.9.3.8. Breakdown rate:

All samples had varying degrees of breakdown rate. There was evidence for a general trend for the untreated samples in the second assessment decreasing in breakdown rate with the increase of CO_2.

Three of the potato samples showed a significant difference for the rate of breakdown, Marfona and Estima in the first assessment and the Estima in the second assessment.

The Marfona tubers showed a significant difference between the untreated and treated samples at the two CO_2 levels, with the untreated tubers (Fig. A57, dark green dotted line) slower to breakdown than the treated samples (Fig. A57, dark green solid line) exposed to equivalent CO_2 levels.

In the case of the Estima tubers, no clear trend was observed to explain the significant difference for the first assessment. The Estima potatoes evaluated in the second assessment appeared affected by their storage and treatment; the treated potatoes (Fig. A58, orange solid line) broke down at a significantly faster rate than those that were untreated (Fig. A58, dotted line), and this difference was accentuated by the increase of CO_2 level.

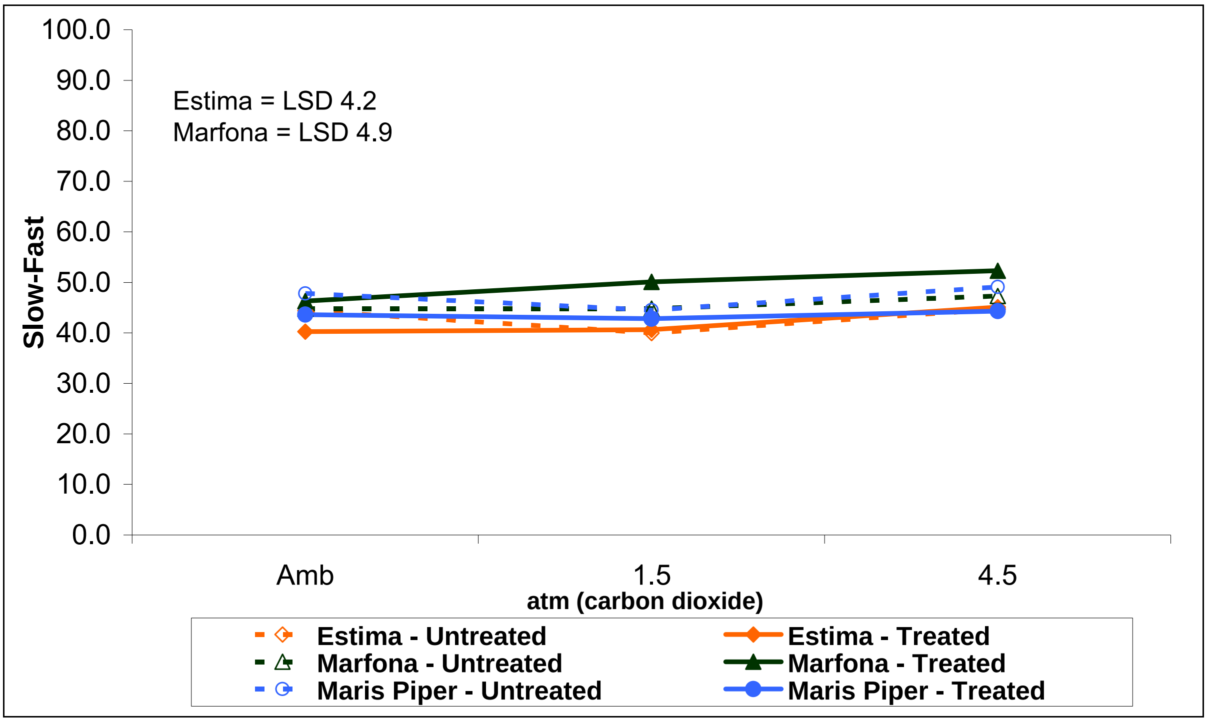


FIGURE A57. BREAKDOWN RATE – ASSESSMENT 1

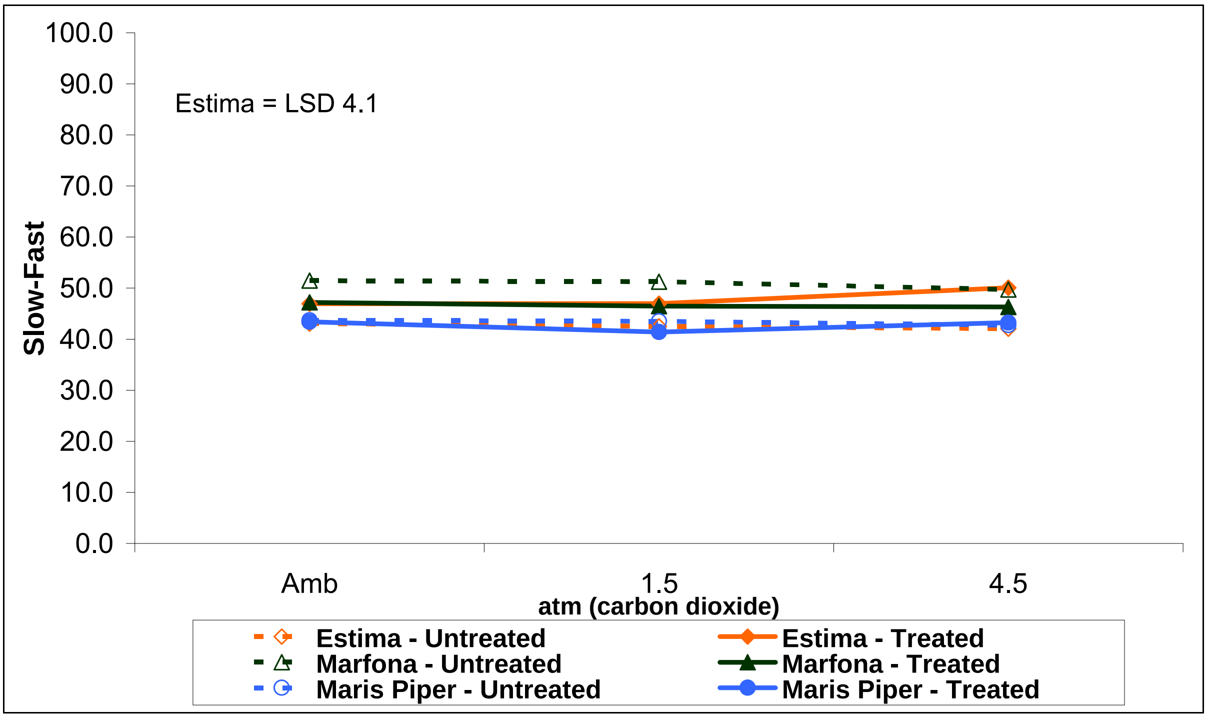


FIGURE A58. BREAKDOWN RATE – ASSESSMENT 2

10.1.9.4. Flavour

A total of 11 attributes were evaluated by the panel. Of these, 4 attributes significantly differentiated the samples. The 4 attributes which were significant in assessment 1 were: *sweet, earthy, metallic* and *cabbage water*. One attribute was significant in assessment 2, *cabbage water*.

10.1.9.4.1. Overall flavour Intensity

The Maris Piper potato in assessment 2 appeared to have the weakest overall flavour, while the others were all of a similar intensity.

10.1.9.4.2. Potato

All the potato varieties exhibited a slight potato flavour, with the Estima variety displaying the greatest level of potato flavour. None of the varieties evaluated showed any significant differences for this attribute.

10.1.9.4.3. Sweet

Overall Maris Piper appeared to be the least sweet of all the potato varieties, with only a very low level of sweetness.
For Estima, similar levels of sweetness were perceived over the two assessment periods, however only those in assessment 1 were significantly different based on CO_2 exposure, with a higher level of CO_2 resulting in a sweeter taste (Fig. A59, orange lines). This trend was not present in the second assessment.
In the case of Marfona potatoes, only assessment 1 displayed significant differences. Similarly to the Estima tuber, it also appeared that the CO_2 level had increased the level of sweetness. This was seen in both the untreated and treated samples at 4.5% CO_2, which were both sweeter than their respective ambient samples (Fig. A59, dark green lines).
No significant difference in sweetness was identified for the Maris Piper potatoes.

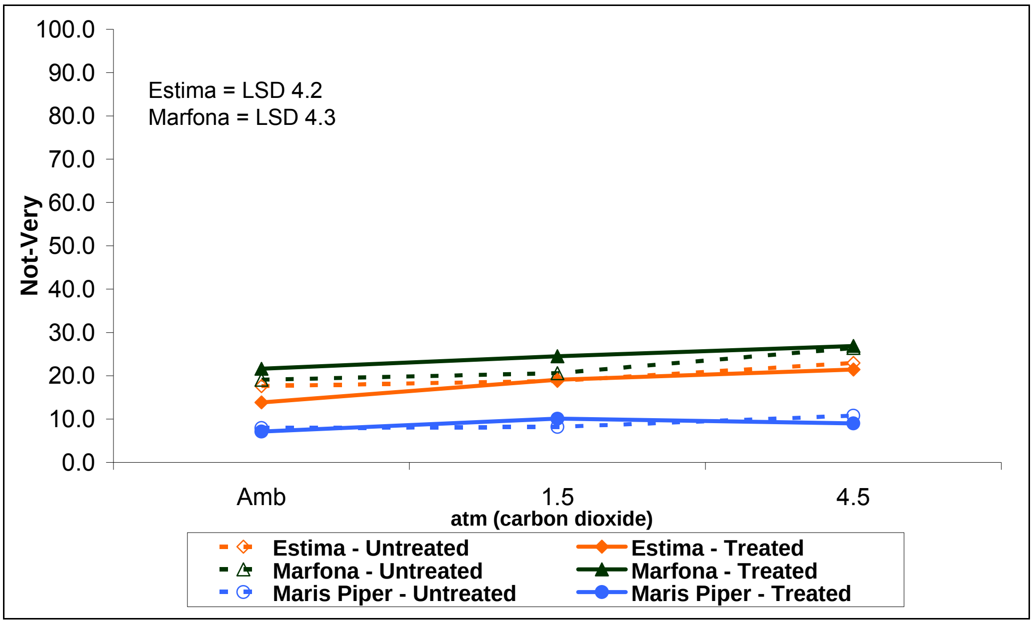


FIGURE A59. SWEET TASTE – ASSESSMENT 1

10.1.9.4.4. Fishy

All sample displayed extremely low levels of the fishy attribute (greatest mean score was 1.6). This suggested that the attribute was not easily detectable; hence no significance could be associated with this attribute.

10.1.9.4.5. Savoury

Similarly to the fishy, no noteworthy levels of savoury were identified at any of the variants, with the greatest mean score of 1.4, and thus no significance could be associated with this attribute.

10.1.9.4.6. Earthy

Low levels of earthy flavour were perceived in all samples, which appeared to decrease in intensity during the second assessment period. It was found to be significant in the Marfona potatoes in assessment 1, where the higher CO_2 levels appeared to decrease the intensity of the Earthy attribute. Figure A60 displays the perceived levels during assessment 1.

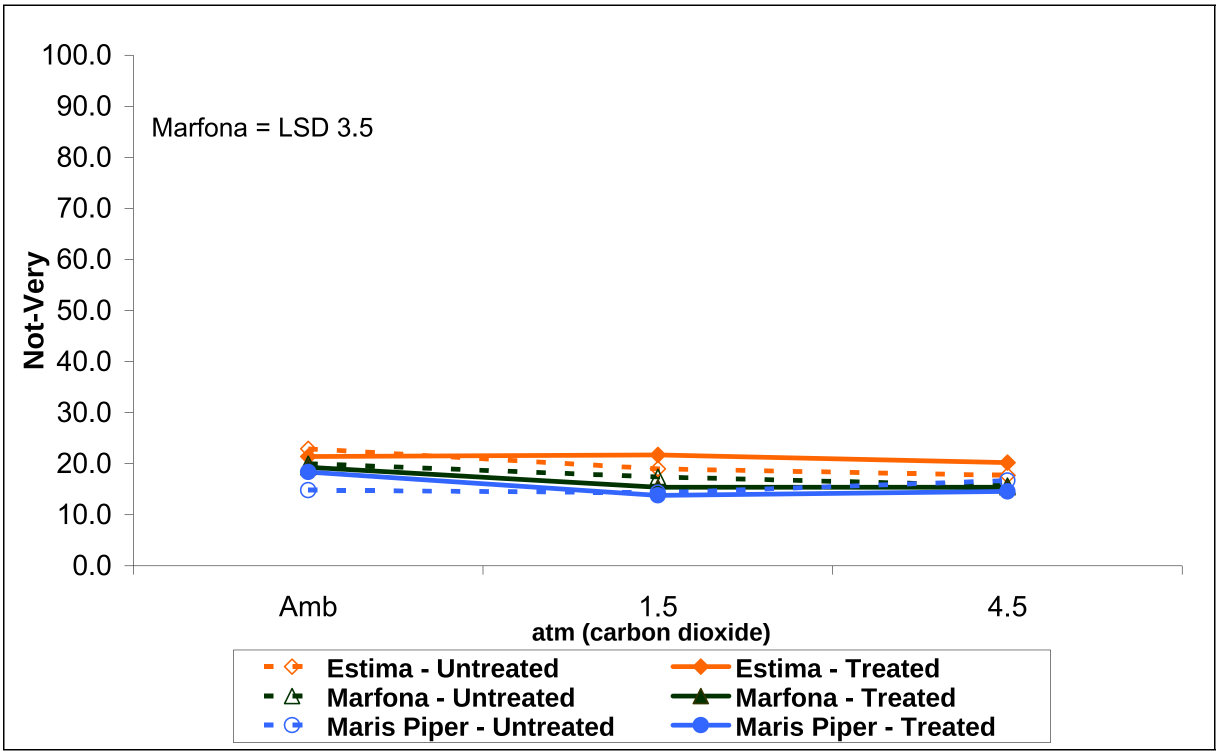


FIGURE A60. EARTHY FLAVOUR – ASSESSMENT 1

10.1.9.4.7. Sour

Overall sourness was not a significant attribute for any variety based on treatment, assessment period or CO_2 level. General trends that were noted for the sour attribute were that it appeared to slightly decrease for each variety during the second assessment phase and that in the Marfona variety, the untreated potatoes were perceived very slightly more sour in taste than those which had been treated.

10.1.9.4.8. Bitter

Very slight levels of bitterness were perceived for all tuber variants, with no significant difference identified. However, in assessment 1, the treated potatoes showed a decrease in bitterness with the increase of CO_2 (all varieties).

10.1.9.4.9. Metallic

All samples displayed very slight levels of metallic. There was a general decrease in the metallic intensity from the first to the second assessment period.

Significant differences were only seen on one sample, Maris Piper (assessment 1). The metallic attribute was significant between the treated and non-treated samples, as well as within the treatments. A very slight decrease in metallic flavour was noted for the treated Maris Pipers in assessment 1, with the treated tubers at the 4.5% CO_2 level being less metallic than the ambient sample (decrease in solid blue line in Figure A61). When comparing the treated and untreated, a significant difference was seen between the ambient samples, with the untreated perceived as being less metallic than the treated (Fig. A61, blue dotted vs. blue solid line). No significant differences were identified when Tukey's HSD was applied.

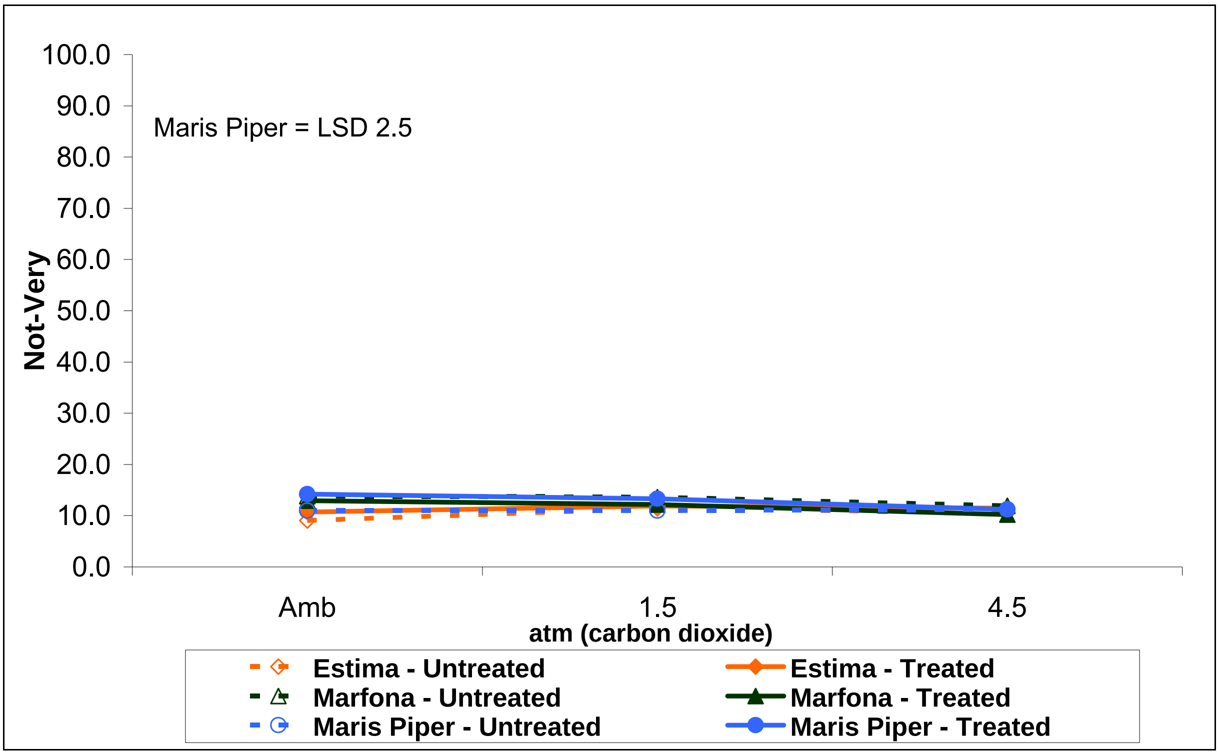


FIGURE A61. METALLIC FLAVOUR – ASSESSMENT 1

10.1.9.4.10. Cabbage water

All samples contained low levels of the cabbage water attribute, which decreased in the second assessment compared to the first assessment point, with the Maris Piper variety having the lowest intensity.
Two of the potato varieties appeared significantly different in cabbage water flavour; Maris Piper (assessment 1) and Estima (assessment 2).

The Maris Piper treated tuber, exposed to 4.5% CO_2 was perceived as least intense in cabbage water flavour. This sample was significantly different using Fisher LSD from all except the untreated 1.5% CO_2 sample, significantly different using Tukey's HSD from treated ambient and untreated 4.5% CO_2. Figure A62 shows the perceived intensities.

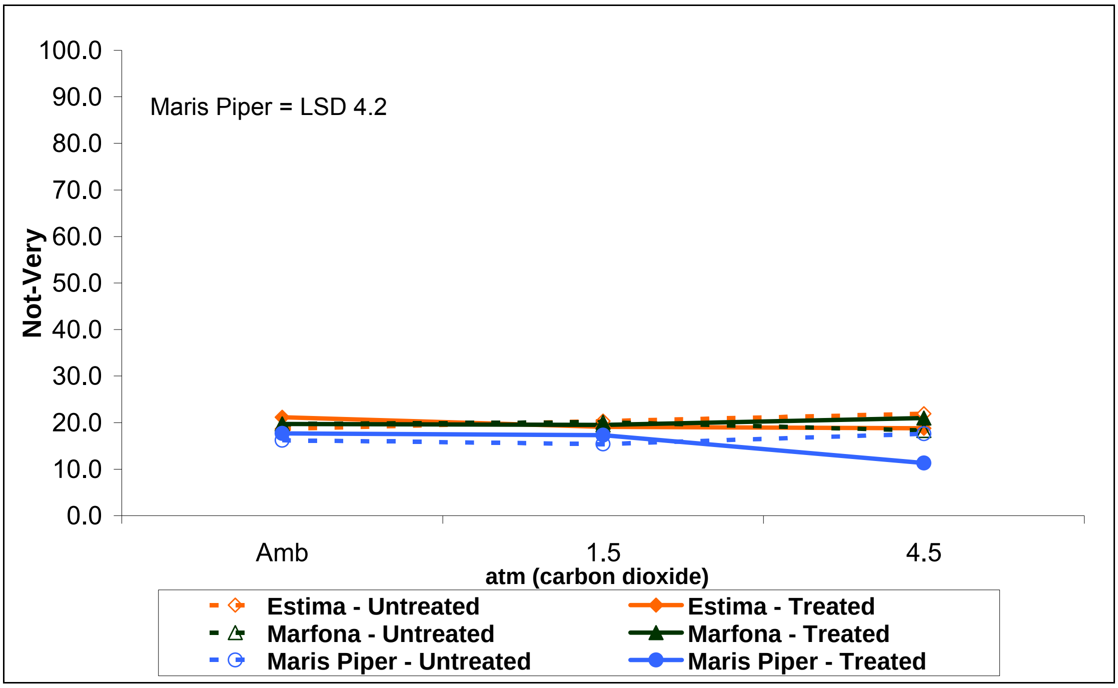


FIGURE A62. CABBAGE WATER FLAVOUR – ASSESSMENT 1

For the Estima potato (assessment 2), treated samples increased in cabbage water flavour with the increase of CO_2. It should be noted that this is the opposite as seen for other potato variants / assessment points, whereby treated potatoes generally decreased with the increase of CO_2. Figure A63 shows the cabbage water flavour intensities found for assessment 2.

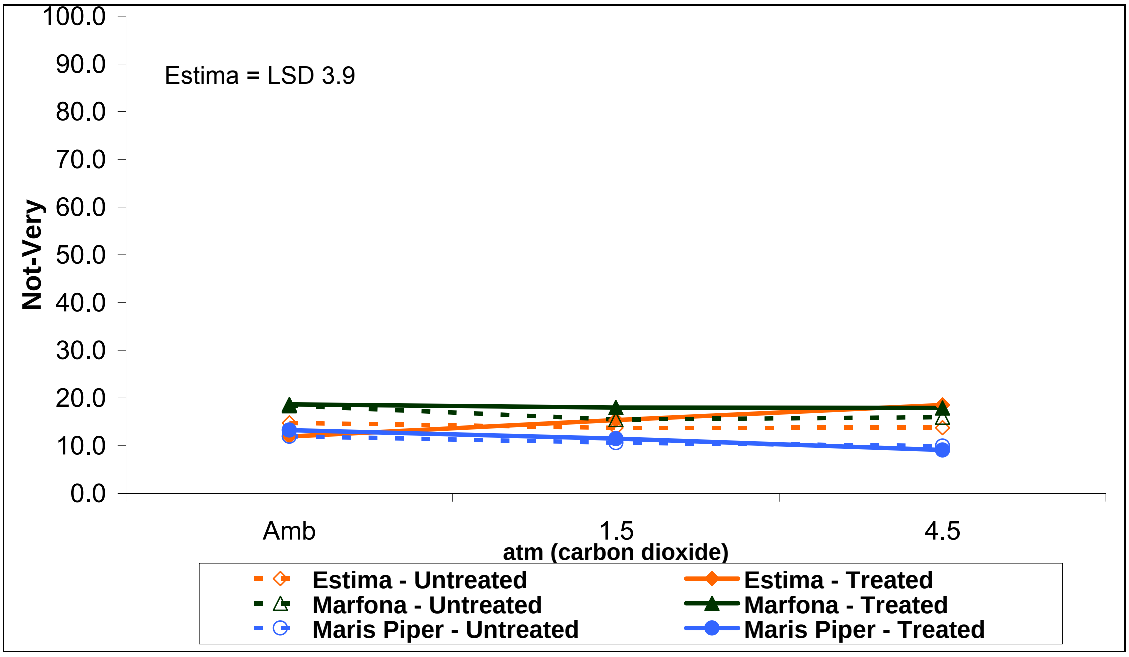


FIGURE A63. CABBAGE WATER FLAVOUR – ASSESSMENT 2

10.1.9.4.11. Off

The off flavour attribute was seen across all tubers at extremely low levels and was not significant in any sample.

10.1.9.5. Aftertaste

A total of 7 attributes was evaluated by the trained panel. A total of 4 attributes significantly differentiated the potato samples. For assessment 1 this was *sweet*, *sour* and *bitter* while for assessment 2 this was *sweet* and *metallic.*

10.1.9.5.1. Overall aftertaste Intensity

All samples left a slight overall aftertaste after swallowing. No significant differences were found the variants.

10.1.9.5.2. Potato

This attribute was of low intensity and was not significant across the potato varieties. The general trend indicated that the potato flavour decreased during the second assessment compared with the first assessment.
During the first assessment, the treated potatoes showed a very slight decrease in potato aftertaste with the increase of CO_2 (all varieties).

10.1.9.5.3. Sweet

Sweet aftertaste was significant for the Estima and Marfona varieties. Treated Estima & Marfona increased in sweet aftertaste with increased levels of CO_2. Furthermore, treated Marfona was sweeter in aftertaste than untreated.

Maris Piper had the lowest level of sweet aftertaste. Figures A64 and A65 show the sweet aftertaste intensities.

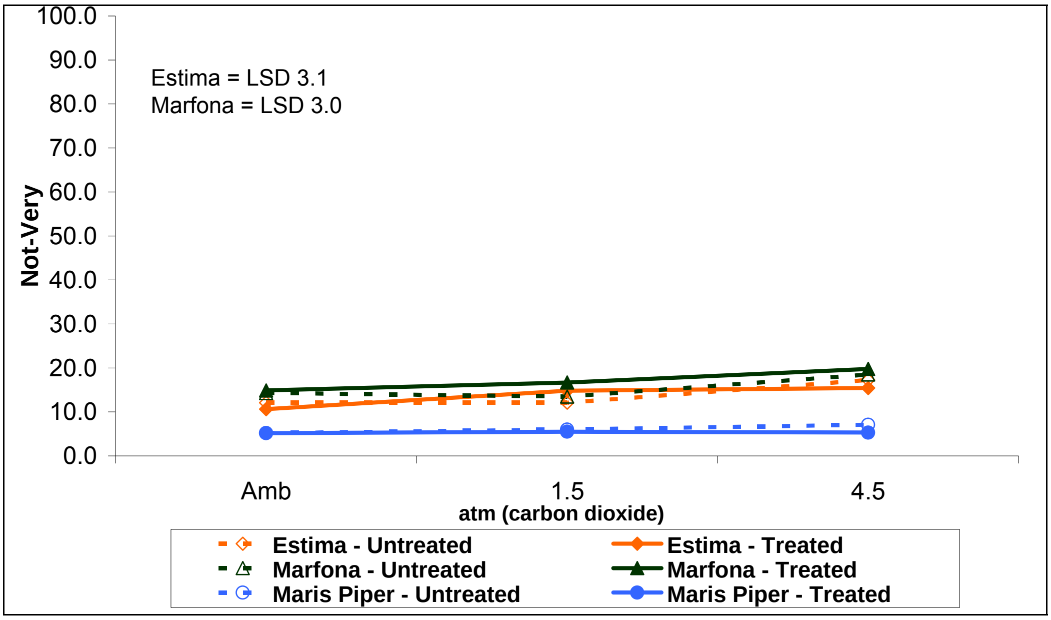


FIGURE A64. SWEET AFTERTASTE – ASSESSMENT 1

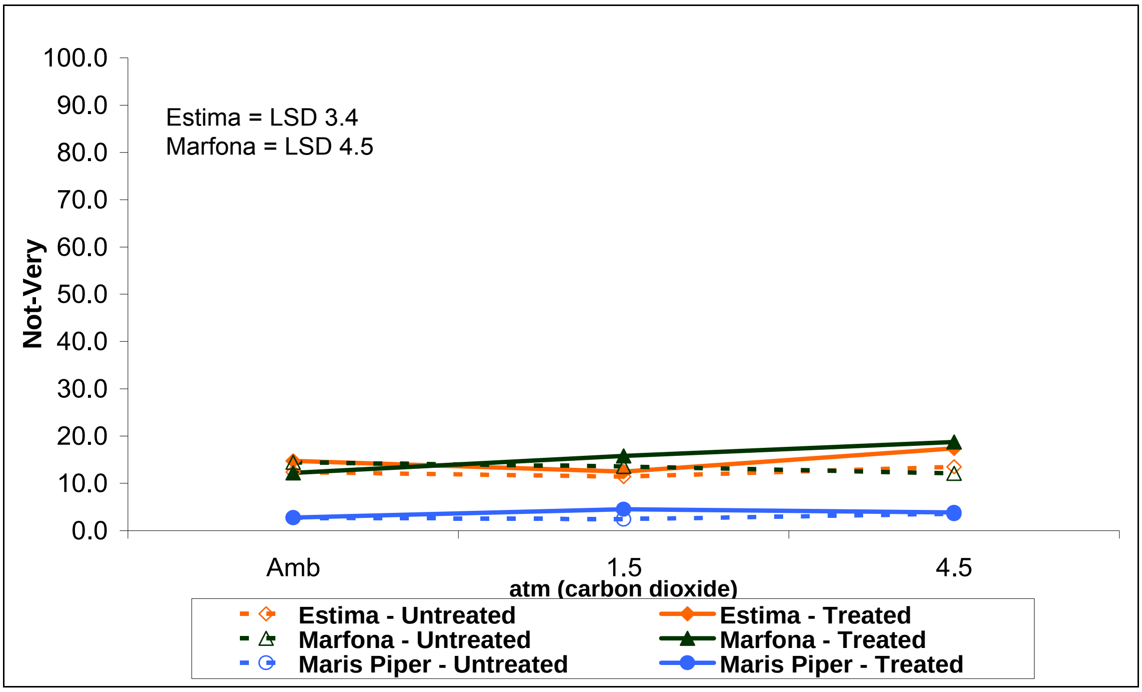


FIGURE A65. SWEET AFTERTASTE – ASSESSMENT 2

10.1.9.5.4. Metallic

The metallic attribute differentiated the Marfona potato samples in assessment 2 only. Using Fisher LSD and Tukey's HSD, the treated ambient sample was more metallic than treated samples exposed to 1.5% and 4.5% CO_2, as shown in Figure A66 (dark green solid line).

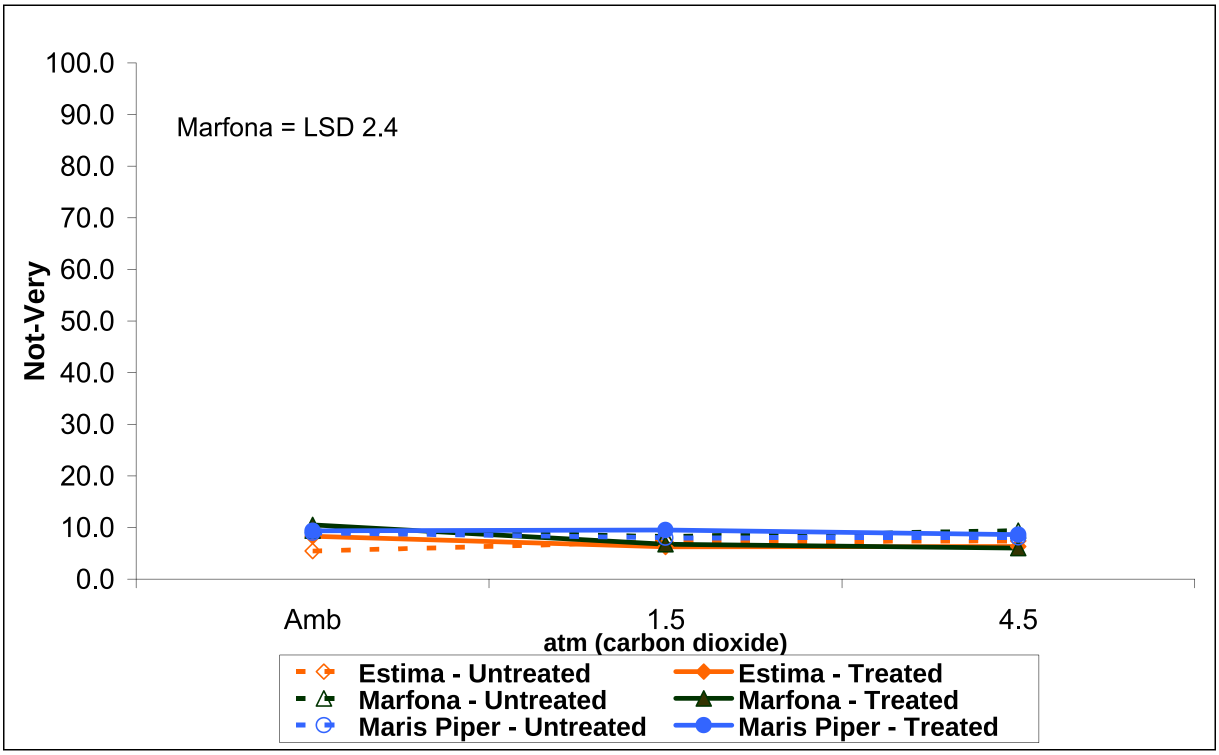


FIGURE A66. METALLIC AFTERTASTE – ASSESSMENT 2

10.1.9.5.5. Earthiness:

Very slight levels of earthy aftertaste were perceived for all potatoes.

10.1.9.5.6. Sourness:

Low levels of sour aftertaste were perceived for the potatoes. Treated Estima assessment 1 and Marfona assessment 1 and 2 potatoes decreased very slightly in sourness with the increase in CO_2 during storage. Untreated Marfona potatoes were slightly more sour than treated Marfona potatoes.

A significant difference was identified for the Marfona potatoes evaluated during assessment 1 only. Using Tukey's HSD, the samples did not differ from each other, indicating a lower confidence in the difference between the Marfona potatoes in sour taste.

Figure A67 shows a graphical display of the sour aftertaste, assessment 1.

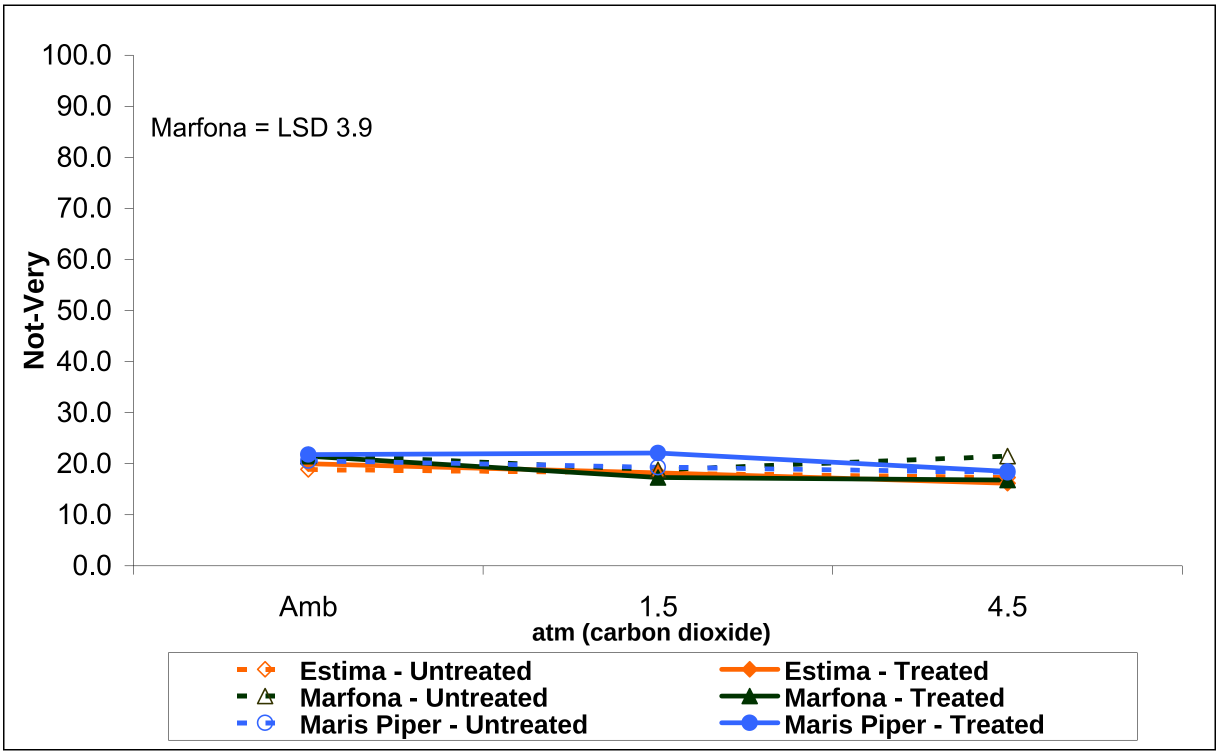


FIGURE A67. SOUR AFTERTASTE – ASSESSMENT 1

10.1.9.5.7. Bitter:

Marfona potatoes in assessment 1 displayed a significant difference in bitter aftertaste, where treated potatoes exposed to CO_2 were slightly less bitter. This trend of decreased bitterness perception of treated potatoes exposed to CO_2 was also noted for Maris Pipers evaluated at assessment 1 and Marfona during assessment 2.
Figure A68 shows the bitter aftertaste of potatoes evaluated in assessment 1.

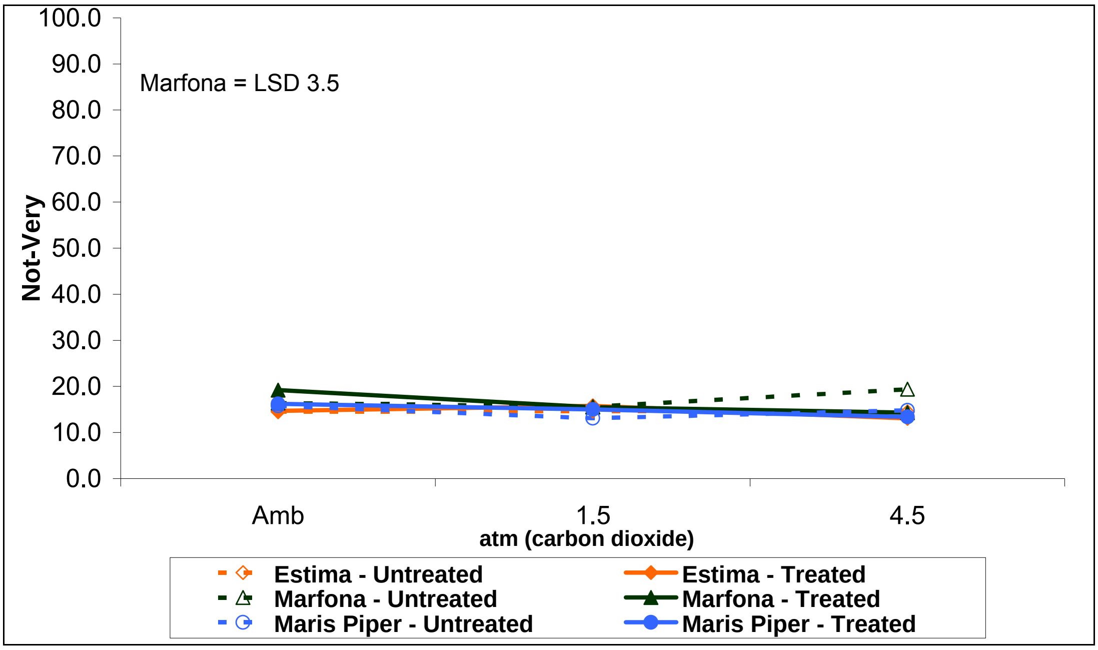


FIGURE A68. BITTER AFTERTASTE – ASSESSMENT 1

10.1.9.6. Afterfeel

The final category that the panel evaluated consisted of three terms, of which 2 attributes were found to be significant. In assessment 1 these were astringent and mouthcoating, while in assessment 2 it was mouthcoating.

10.1.9.6.1. Astringent

Astringency was only significant in the Marfona evaluated in assessment 1. Although the difference between samples was not very clear, exposure of the treated samples to CO_2, appeared to lower the astringency. Tukey's HSD did not differentiate the samples. Figure A69 displays the astringent afterfeel during assessment 1.

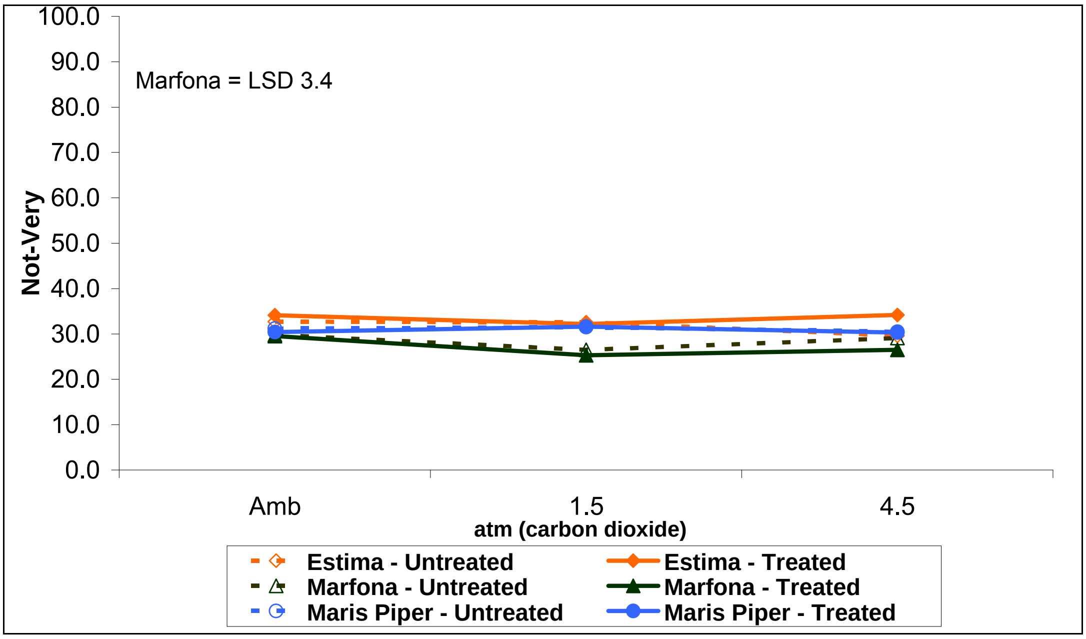


FIGURE A69. ASTRINGENT AFTERFEEL – ASSESSMENT 1

10.1.9.6.2. Mouthcoating

The strongest mouthcoating afterfeel was perceived in the Maris Piper potatoes.

Significant differences were seen in the Marfona potatoes in both assessments. In assessment 2, the treated samples appeared to be more mouthcoating that the untreated samples. In assessment 1, the trend was less clear, and if any, the opposite was seen to assessment 2, where treated CO_2 exposed samples were giving less mouthcoating in afterfeel than untreated CO_2 exposed Marfona potatoes.

Graphical representation for both assessment points is shown in Figures A70 and A71.

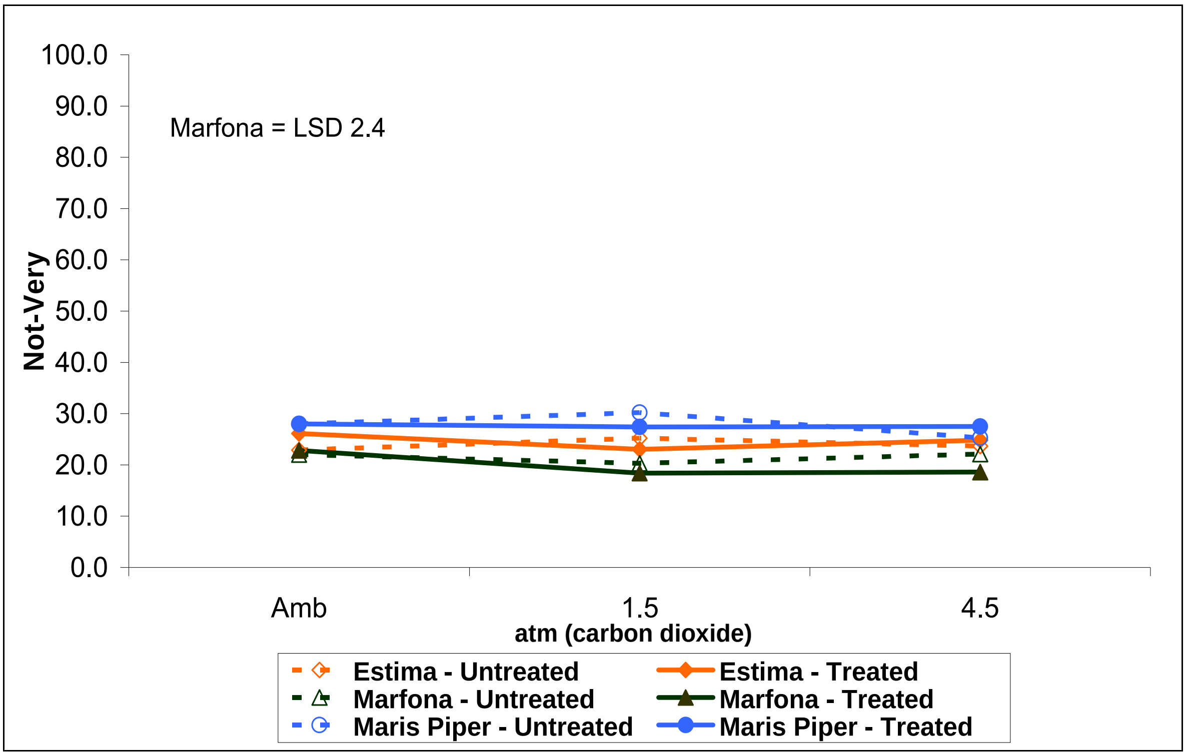


FIGURE A70. MOUTHCOATING AFTERFEEL – ASSESSMENT 1

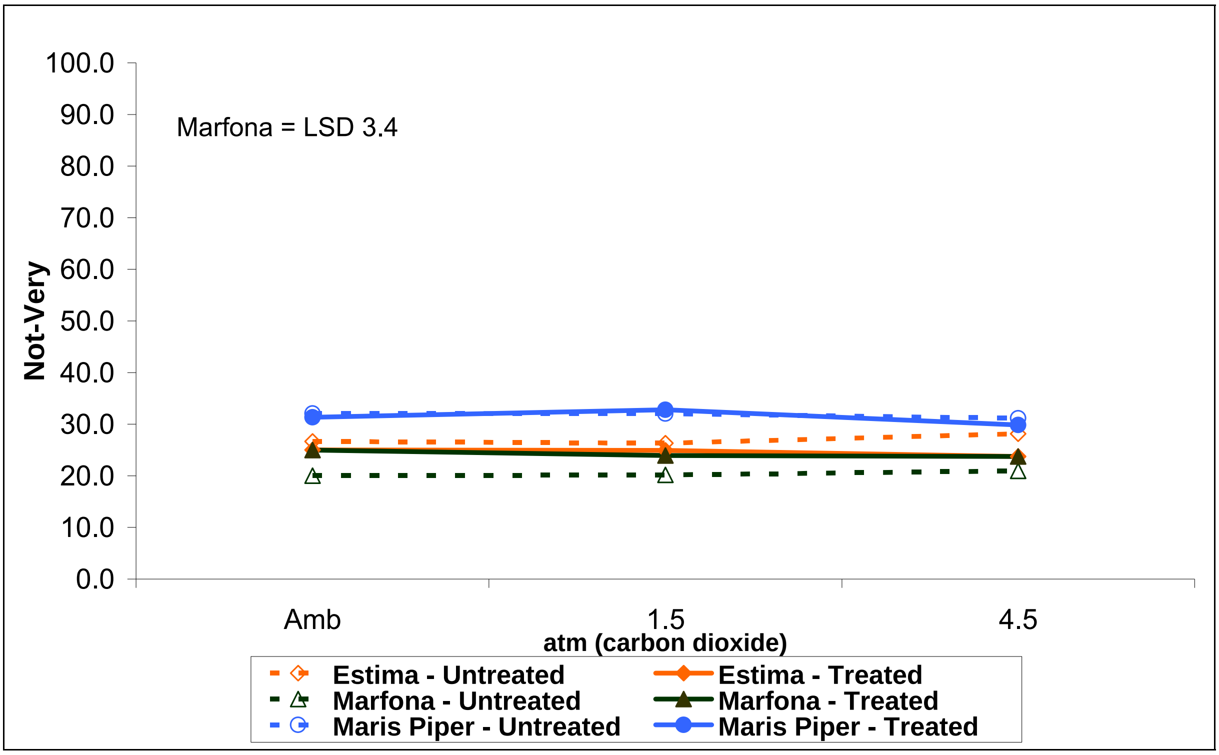


FIGURE A71. MOUTHCOATING AFTERFEEL – ASSESSMENT 2

10.1.9.6.3. Irritant:

This attribute was non-significant across all samples.

10.1.10. Principal Component Analysis

Principal Component Analysis (PCA) is a multivariate statistical technique, which can be applied to data sets comprising more than four samples to create a map which explores the perceptual relationships between those samples. PCA is used to reduce the dimensionality of complex data sets in such a way that the main information on the perceived relationships is contained in a limited number of two-dimensional plots. In these plots, closely positioned samples are perceived as very similar in the dimensions plotted, whereas samples positioned well apart are perceived as very different. The reasons for the sample positioning are interpreted using the original sensory attributes, which are plotted as vectors radiating from the origin. Samples positioned close to an attribute vector are strongly loaded on that attribute.

In order to view the effect of time over the full data set, the data obtained in assessment 1 and 2 were combined. Any assessor who had not evaluated all the samples over the two assessment periods was removed.

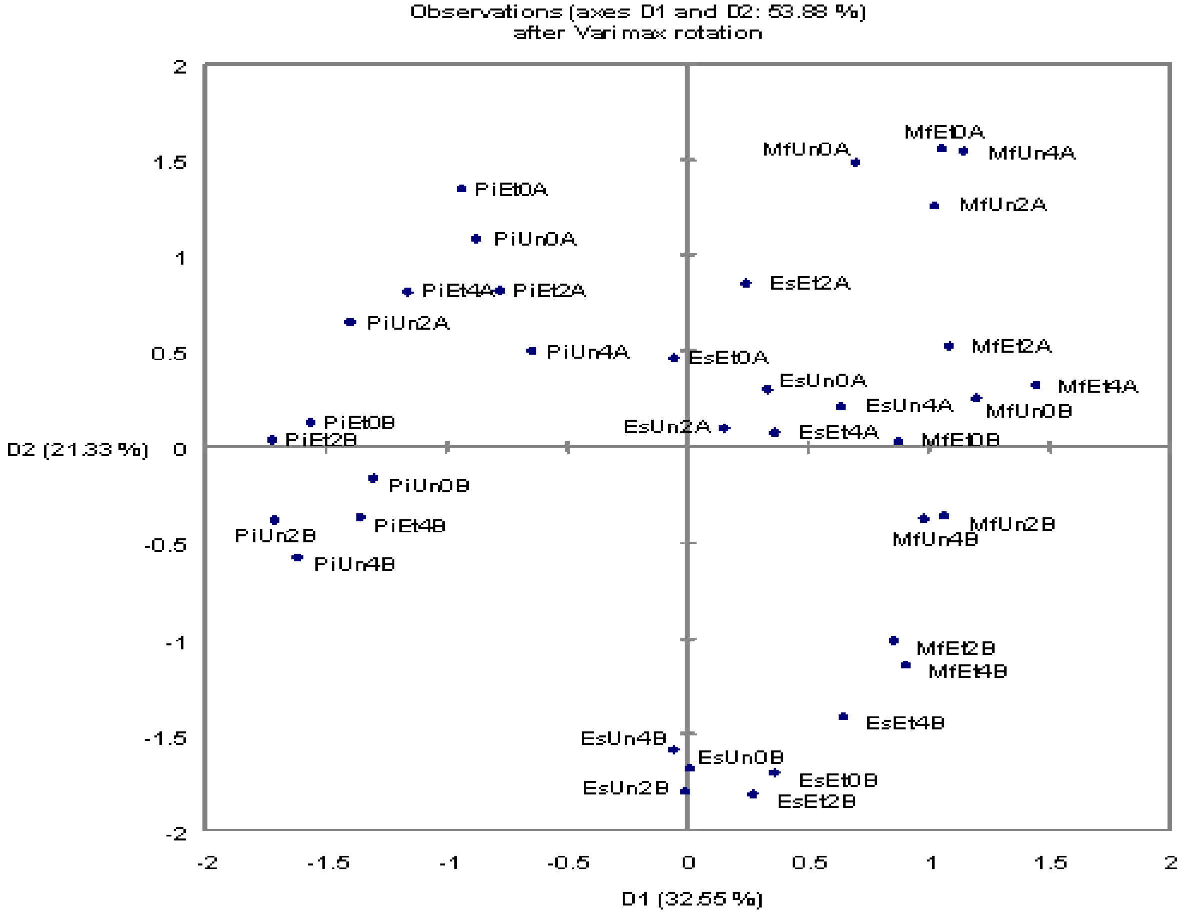
This edited data set was then analysed using PCA. The plots produced indicated that 53% of the data was explained on the first two dimensions (Figure. A72). Dimension 1 accounted for 32% of the total data, while dimension 2 explained 21% of the data.

The plot indicated that the potato varieties separated along dimension 1, with Maris Pipers situated on the left side of the plot opposite to Estima and Marfona. The Estima and Marfona varieties were associated with a Sweet flavour and aftertaste, an earthy aroma, break down rate and a waxy texture (Figure. A73).

Dimension 2 appears to be associated with the assessment period, with the samples profiled in January situated at the top of the chart polar to those tested in June. Attributes which were associated with the samples tested in June included blackening appearance, mottled appearance, floury texture, and a smooth appearance, compared to those tested in January which were associated with a metallic aftertaste, an earthy aroma, bitter aftertaste and sweet flavour and aftertaste..

In order to see how the data had divided, dimensions 3 and 4 were also examined, as shown in Figures A74 and A75. These two further dimensions explained an additional 23% of the total data. Dimension 3 was defined by the potato varieties, with Estima positioned on the right of the plot, opposite to Maris Piper and Marfona.

The results for the PCA showed that no simple groupings can be seen according to variety, time, ethylene, or CO_2 apart from the following: the effect of the ethylene treatment and the CO_2 levels on the potatoes appeared to be evenly distributed, and so were not seen to have a significant effect.



Key:
PI= Maris Piper, **Es**= Estima, **Mf**= Marfona, **Un**=Untreated, **Et**= Ethylene, **0**=Ambient CO2, **2**= 1.5 CO2, **4**=4.5 CO2, **A**= January, **B**= June

FIGURE A72. PRINCIPAL COMPONENT ANALYSIS OF ASSESSED POTATO SAMPLES – DIMENSIONS 1 AND 2

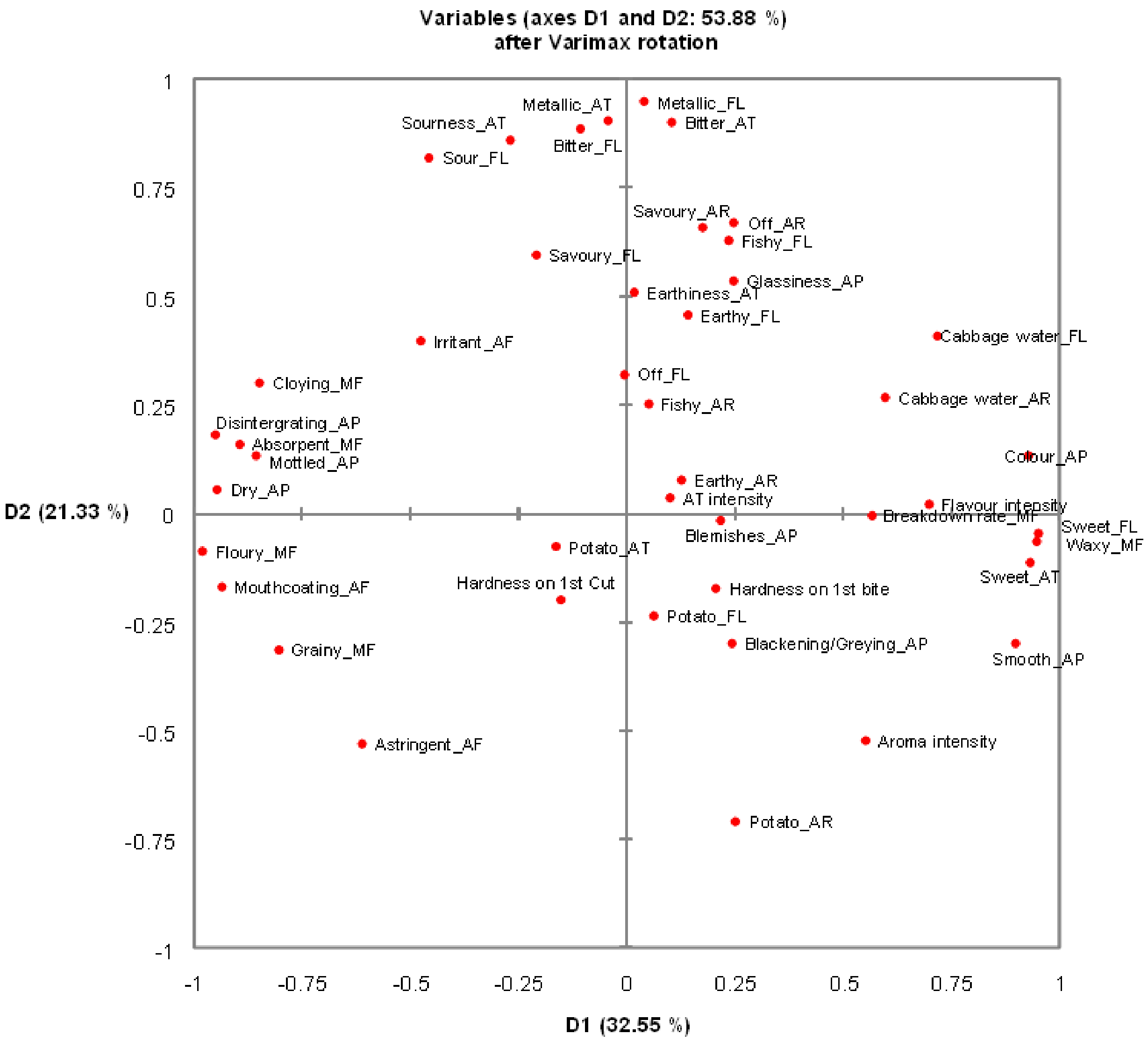


FIGURE A73. PRINCIPAL COMPONENT ANALYSIS – ALL ATTRIBUTES, DIMENSION 1 AND 2

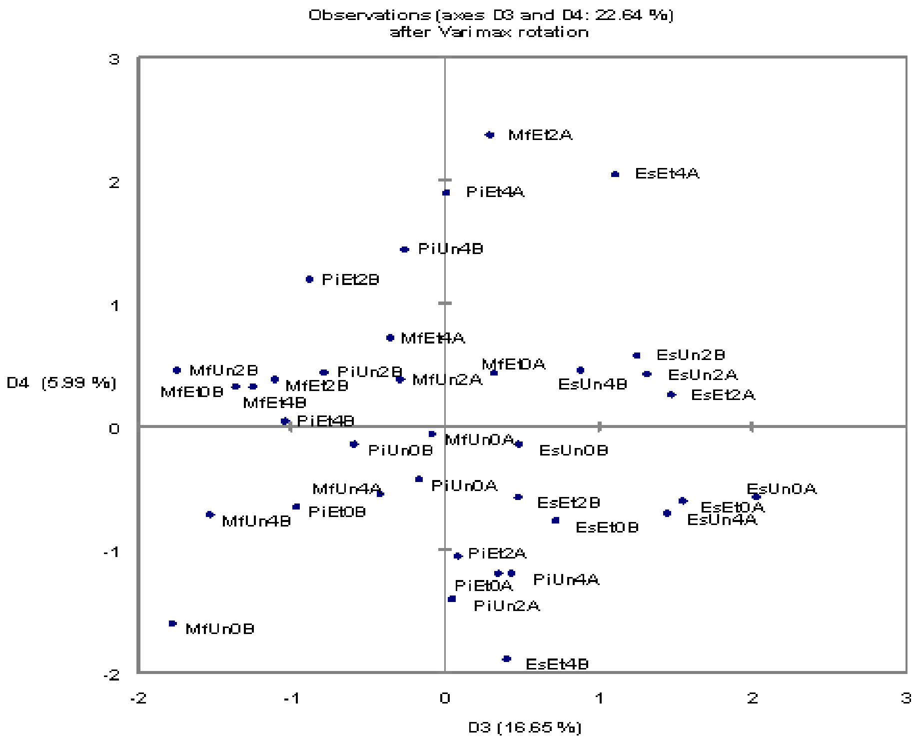


FIGURE A74. PRINCIPAL COMPONENT ANALYSIS OF ASSESSED POTATO SAMPLES – DIMENSION 3 AND 4

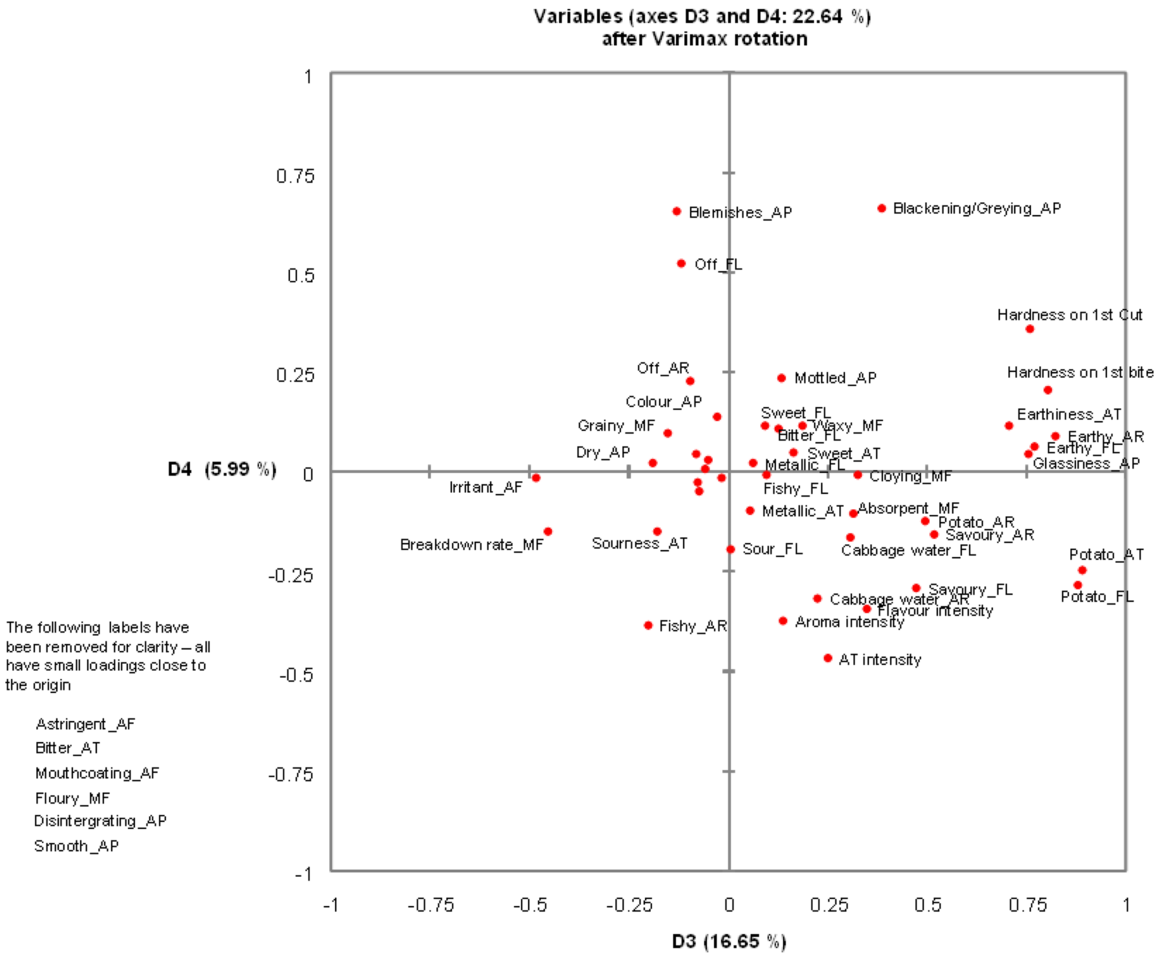


FIGURE A75. PRINCIPAL COMPONENT ANALYSIS, ALL ATTRIBUTES DIMENSION 3 AND 4.

10.1.11. General Linear Model

To determine if there were any interactions between the ethylene treatments, assessment period or CO_2 levels used, which may have affected the perceived attributes of each potato, General Linear Modelling was used. The raw data was clustered into eight suitable groups, based on the attribute position on the PCA plots:

1. Crumbly/dry
2. Sour/Bitter/Metallic
3. Potato/Earthy
4. Hard/Savoury
5. Sweet/Intense
6. Off Notes
7. Bad Appearance (blemishes & blackening/greying)
8. Aromatic

Analysis of the four main effects; potato variety, ethylene, CO_2 and time against the 8 clusters indicated the following:

- The attributes associated with each of the clusters were significantly affected by the potato variety
- The results showed that ethylene, had a significant effect on cluster 8- bad appearance.
- CO_2 levels appeared to have a significant effect on cluster 2 - sour/ bitter/ metallic
- Time appeared to affect clusters 2, 4, 5, 6 and 8.

As the four main factors showed little direct sign of affecting the 8 clusters, Analysis was carried out to examine the various interactions between the four main effects: potato variety, ethylene, CO_2 and time. The results showed that a few of the interactions produced significant effects on the clusters. The main interactions which were significant were:

- Time by Ethylene
- Variety by Ethylene
- Time by Variety by Ethylene

10.1.11.1. Time by Ethylene

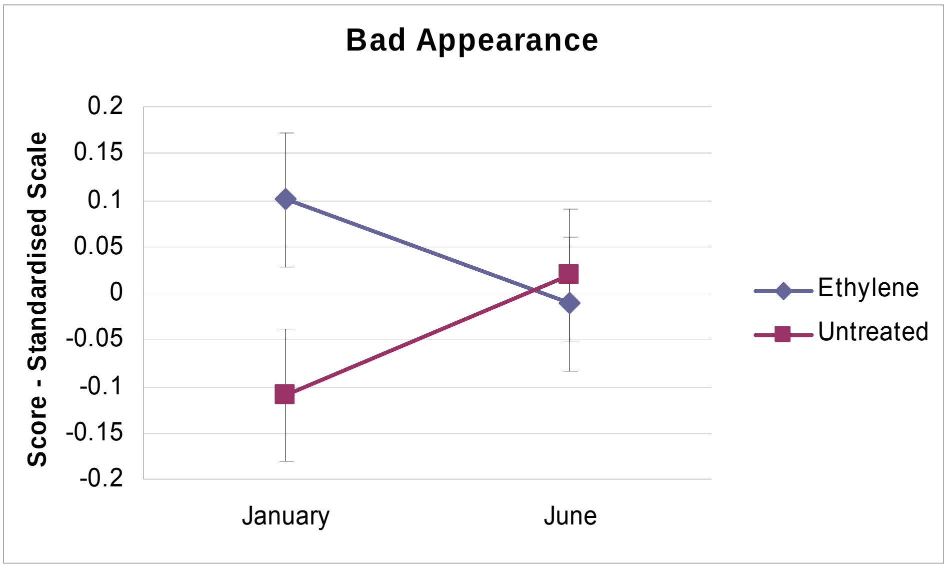


FIGURE A76. TIME BY ETHYLENE EFFECT ON 'BAD APPEARANCE'

The results showed that the bad appearance cluster was affected by the interaction of time and ethylene treatment as shown in Figure A76. The results showed that there was a significant difference between the treated and untreated potatoes during the first assessment period, with the potatoes in the first assessment scoring higher on the attributes contributing to bad appearance, than in the second assessment.

10.1.11.2. Variety by Ethylene

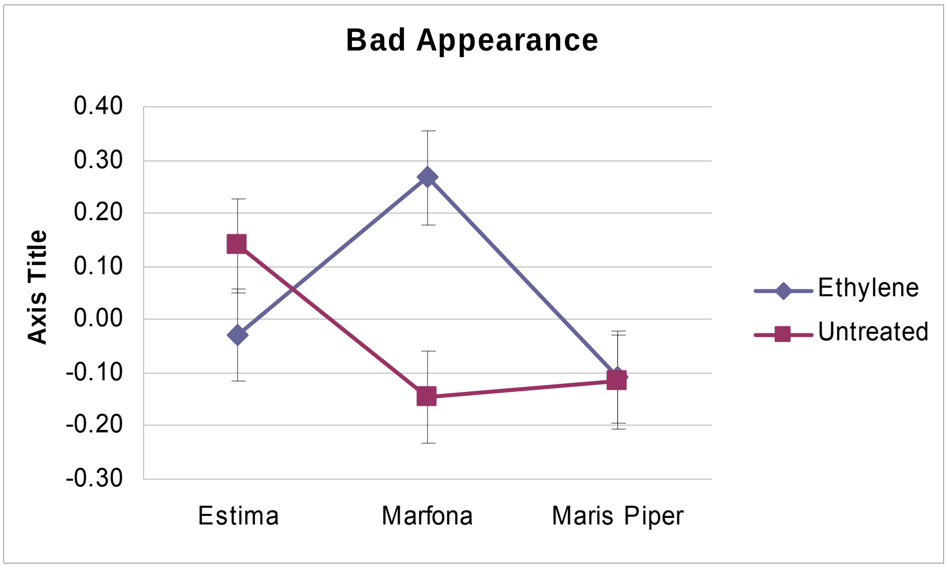


FIGURE A77. VARIETY BY ETHYLENE EFFECT ON 'BAD APPEARANCE'

The interaction between the variety and Ethylene were also examined. The results showed that across both treatments and all three varieties, the bad appearance cluster showed significant differences. The Marfona tubers were affected more than the other two varieties by the Ethylene. The treated Marfona tubers scored higher on those attributes in the bad appearance cluster, a graphical display is shown in Figure 37.

10.1.11.3. Time by Variety by Ethylene

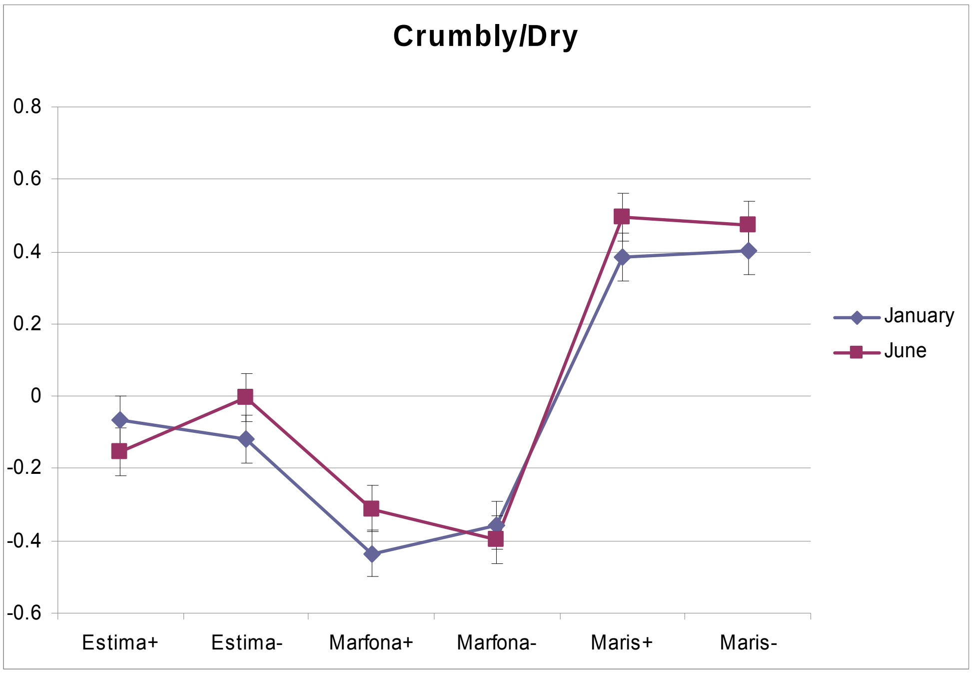


FIGURE A78. TIME BY VARIETY EFFECT ON 'CRUMBLY/DRY'

As time, variety and ethylene appeared to have an effect on the tubers to a small degree, it was felt it would be appropriate to investigate if there was an interaction between all three factors.

The results indicated that the crumbly/ dry cluster showed a significant difference. Overall it would appear that the Marfona variety was significantly affected by the ethylene treatment, while the Estima and Maris Piper were not significantly affected (Figure A78). The levels of CO_2 present did not appear to produce any significant changes to the perceived attributes.

10.1.12. Summary 2009

Table A28 below summarises the significant attributes by variety for the two assessment periods (January - 1 and June- 2)

		Estima 1	Estima 2	Marfona 1	Marfona2	Maris Piper 1	Maris Piper2
aroma	Overall aroma intensity						
	Potato						
	Fishy						
	Savoury						
	Earthy	✓					
	Cabbage water						
	Off						
Appearance	Colour						
	Smooth	✓					
	Dry					✓	
	Blemishes				✓		
	Glassiness						
	Blackening / Greying	✓	✓	✓			
	Mottled			✓			
	Surface Disintegrating						
Texture / mouthfeel	Hardness on 1st Cut			✓	✓		
	Hardness on 1st bite			✓		✓	
	Absorbent						
	Waxy	✓		✓			
	Floury			✓		✓	
	Cloying		✓	✓			
	Grainy			✓			
	Breakdown rate	✓	✓	✓			
Flavour	Overall flavour intensity						
	Potato						
	Sweet	✓		✓	✓		
	Fishy						
	Savoury						
	Earthy			✓			
	Sour						
	Bitter						
	Metallic				✓	✓	
	Cabbage water		✓			✓	
	Off						
Aftertaste	Overall aftertaste intensity						
	Potato						
	Sweet	✓	✓	✓			
	Metallic			✓			
	Earthiness			✓			
	Sourness			✓			
	Bitter			✓			
After feel	Astringent			✓			
	Mouthcoating			✓	✓		
	Irritant						

TABLE A28: SUMMARY TABLE SIGNIFICANT DIFFERENCES

10.1.12.1. Estima

Estima appeared to be a fairly stable variety over the testing period with 7 significant differences at assessment 1 reducing to 5 significant differences at assessment 2. Three of these significant differences were across the same attributes namely the rate of breakdown, sweet aftertaste and blackening/greying appearance.

10.1.12.2. Marfona

Marfona tubers appeared the most distinctive of all the three tubers. Samples which were evaluated in assessment period 1 had the highest number of significant attributes, concentrated within the texture and aftertaste categories. Attributes which were consistently significant at the two assessment points were hardness on first cut, sweet flavour and mouthcoating in the afterfeel modality.

10.1.12.3. Maris Piper

Maris Piper appeared to be the most stable and unaffected of the three potato varieties. During the first assessment period five significant attributes differentiated the variously treated samples, however the number of significant attributes decreased to zero after the six month storage period.

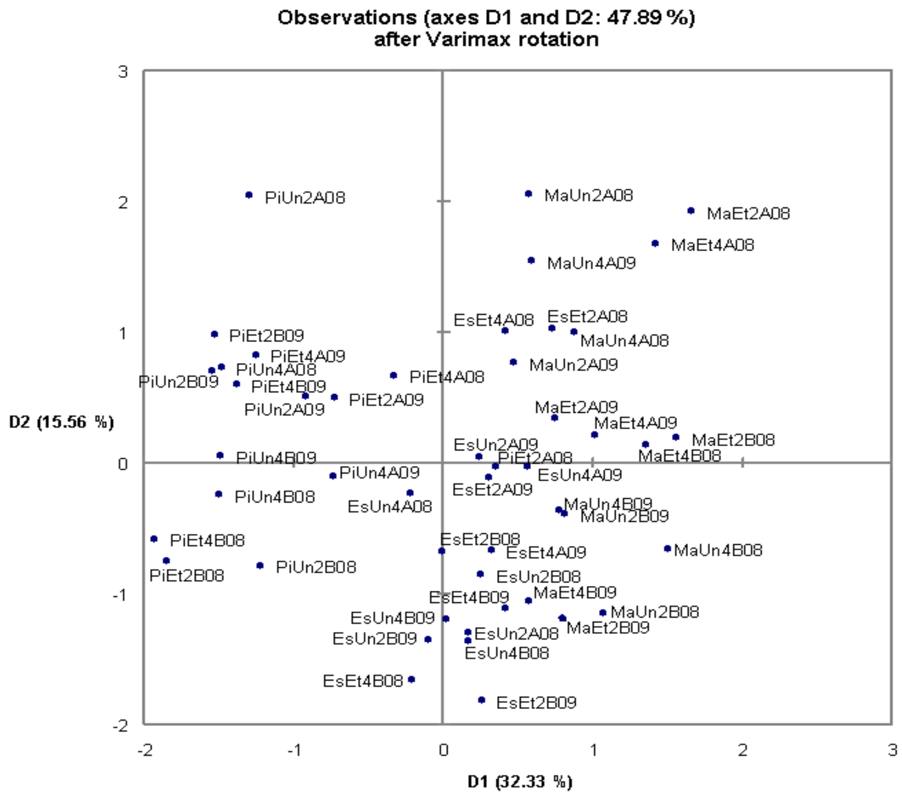
11. ANNEX 3 LFI REPORT SUMMARY OF COMBINED YEARS ANALYSIS OF STORE CARBON DIOXIDE AND ETHYLENE LEVEL EFFECTS ON POTATO FLAVOUR AND TEXTURE

Using the samples that were common to all tests, the data from both years was combined. The data from any assessors not taking part in all four sessions was removed to eliminate any unwanted variation due to the assessors themselves.

The varimax PCA of this combined data set is shown in figures 79-82. The suffixes “08” and “09” are used to distinguish the two years. The potato variety appeared to be the major factor distinguishing the samples, followed by time.

The potato variety appeared to separate along the first two dimension (figure A79), with Maris Piper situated on the left side of the plot opposite to Estima and Marfona, both of which were situated on the right of the plot.

The time between samples, also appeared to effect the position of the potatoes, with samples appearing within the sample section of the plot, but not appearing to be identical to each other.



Key:
Pi= Maris Piper, **Es**= Estima, **Ma**= Marfona, **Un**=Untreated, **Et**= Ethylene, **0**=Ambient CO2, **2**= 1.5 CO2, **4**=4.5 CO2, **A**= January, **B**= June, **08**=2008 assessment, **09**=2009 assessment

FIGURE A79. PRINCIPAL COMPONENT ANALYSIS 2008 & 2009 – DIMENSIONS 1 & 2.

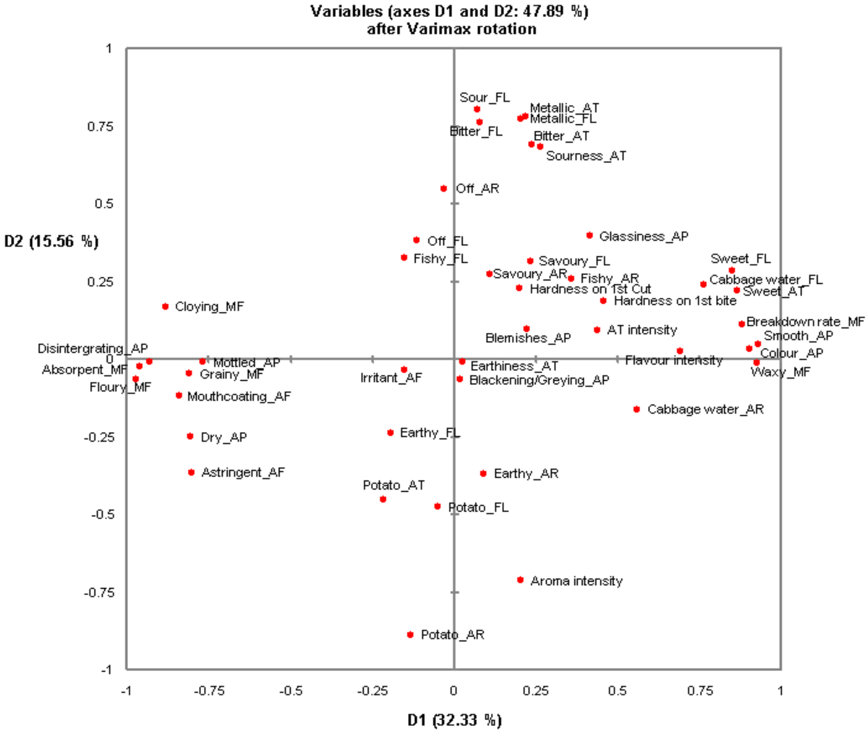
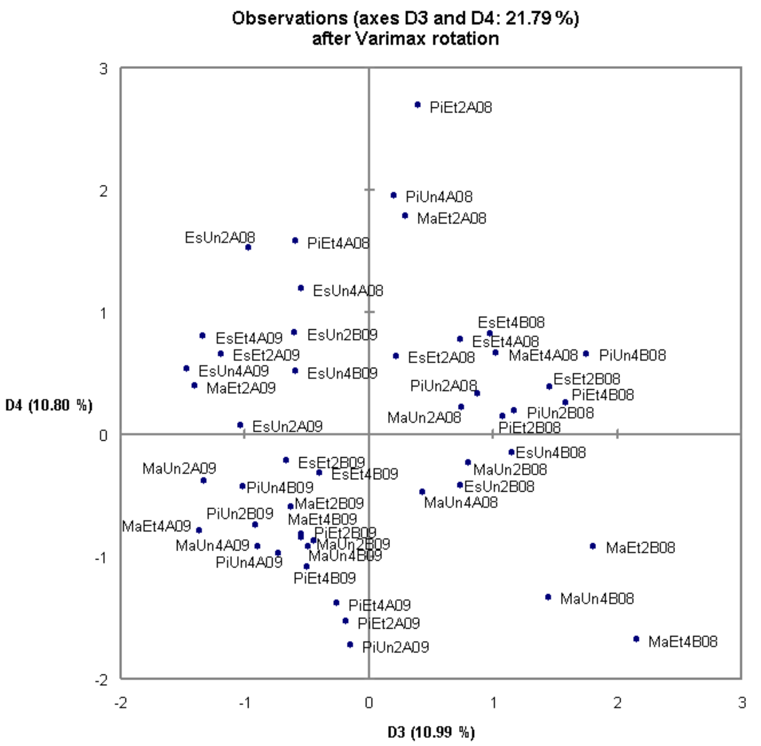


FIGURE A80. PRINCIPAL COMPONENT ANALYSIS – ALL ATTRIBUTES 2008 & 2009 ANALYSIS, DIMENSION 1 & 2



Key:
PI= Maris Piper, **Es**= Estima, **Ma**= Marfona, **Un**=Untreated, **Et**= Ethylene, **0**=Ambient CO_2, **2**= 1.5 CO_2, **4**=4.5 CO_2,
A= January, **B**= June, **08**=2008 assessment, **09**=2009 assessment

FIGURE A81. PRINCIPAL COMPONENT ANALYSIS 2008 & 2009 – DIMENSIONS 3 & 4.

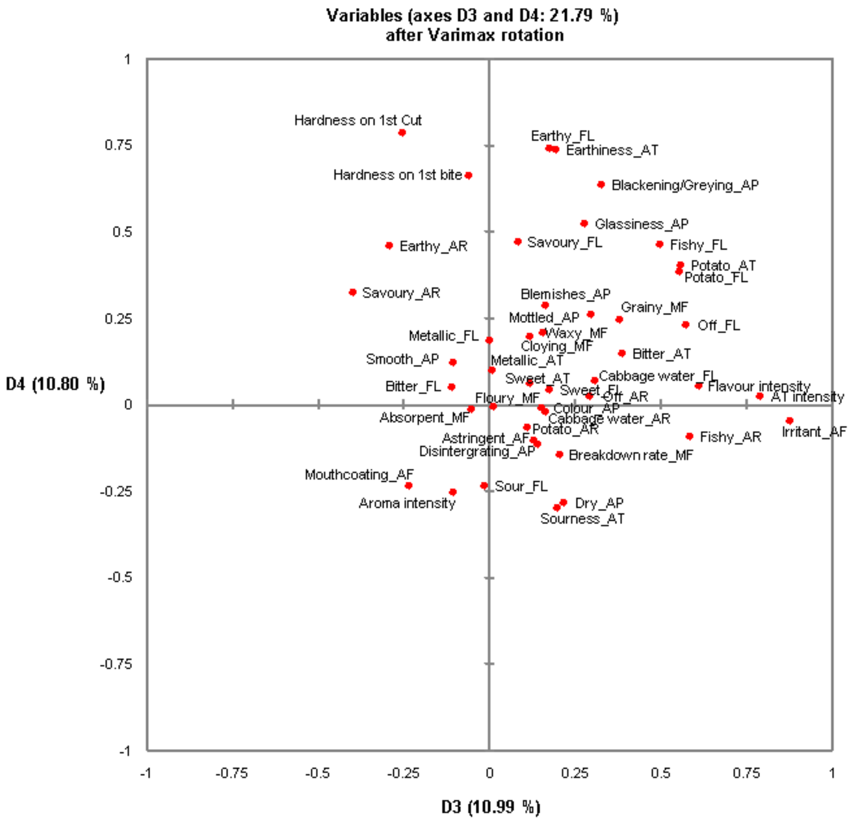


FIGURE A82. PRINCIPAL COMPONENT ANALYSIS – ALL ATTRIBUTES 2008 & 2009 ANALYSIS, DIMENSION 3 AND 4

11.1.1. Influencing Factor Percentages

Five main factors were examined for the duration of this project. They were Variety, Ethylene, CO2, Month and year. In order to determine the influence/ contribution, ANOVA was carried out on these factors for dimension 1- 4 of the PCA plot: (Table 11 – 14)

Dimension	Source	P value	Variance Explained
d1	variety	0.0000	81.8%
d1	ethylene	0.0765	1.2%
d1	CO2	0.6507	0.1%
d1	month	0.0213	2.0%
d1	year	0.1729	0.7%

TABLE A29 INFLUENCE OF FACTORS FOR SAMPLE ON DIMENSION 1

Table A29 indicates that the main factors influencing the data were variety , accounting for 82% of the results, along with month of testing, which accounted for 2% of the results.

Dimension	Source	PROB	Variance Explained
d2	variety	0.0002	**21.0%**
d2	ethylene	0.8246	0.0%
d2	CO2	0.7447	0.1%
d2	month	0.0000	**36.9%**
d2	year	0.3530	0.9%

TABLE A30 INFLUENCE OF FACTORS FOR SAMPLE ON DIMENSION 2

Dimension	Source	PROB	Variance Explained
d3	variety	0.0874	2.6%
d3	ethylene	0.2230	0.8%
d3	CO2	0.7226	0.1%
d3	month	0.0000	**13.2%**
d3	year	0.0000	**62.6%**

TABLE A31 INFLUENCE OF FACTORS FOR SAMPLE ON DIMENSION 3

Dimension	Source	PROB	Variance Explained
d4	variety	0.0089	**14.1%**
d4	ethylene	0.5965	0.4%
d4	CO2	0.5965	0.4%
d4	month	0.0076	**10.5%**
d4	year	0.0004	**20.2%**

TABLE A32 INFLUENCE OF FACTORS FOR SAMPLE ON DIMENSION 4

The majority of data from the PCA was explained on the first 4 dimensions. Variety was the most important factor, influences the position of samples on the first, second and fourth dimensions. On the first dimension it accounted for 82% of the overall results. The month and year of testing appeared to be the second most significant factor. This affected all four dimensions. Its main influence appeared to be on dimension 3 where it accounted for over 75% of the results. Neither the CO_2 level nor the ethylene appeared to be significant factors on any of the dimensions, and explained a small amount of the results.

11.1.2. Discussion

11.1.2.1. 2008 versus 2009 assessments

The main differences seen throughout these trials were attributed to the potato variety, this being supported by the evidence of the high influencing percentages, followed by differences observed by testing time point. Very little effect was seen due to the ethylene treatment and even less by the carbon dioxide condition.

The main basis for the sensory differences identified over the course of the test programme, were for the potato variety as seen in the combined PCA where the Maris Piper was most different from the Marfona and Estima.

For time, a combination of month and year were examined. The data showed that time was influenced the position of samples on D3, accounted for 75% of the results, indicating that differences had occurred over the storage time period.

Treatment with ethylene gave some differences in the 2008 assessment; however these trends were not consistent with 2009. Marfona may be an exception, with treated variants being slightly sweeter than their untreated equivalents

Carbon dioxide very slightly differentiated the samples evaluated in 2009 only.

11.1.3. Tukey's HSD

	Untreated			Treated				
	Ambient	**1.5**	**4.5**	**Ambient**	**1.5**	**4.5**	**HSD**	**p Value**
Aroma								
Overall aroma intensity	38.6	37.5	40.4	39.8	38.3	36.8	5.1	0.3115
Potato	28.9	28.4	27.2	27.6	26.7	27.8	4.5	0.7114
Fishy	3.1	2.0	2.7	2.2	4.0	1.5	3.2	0.2933
Savoury	3.1	2.5	5.3	1.7	3.8	1.3	5.3	0.2603
Earthy	23.2	15.3	18.3	15.9	18.2	19.8	7.6	**0.0413**
Cabbage water	21.9	22.5	21.2	23.7	22.6	20.0	6.1	0.5550
Off	0.6	0.5	1.1	0.8	0.8	1.7	2.4	0.7234
Appearance								
Colour	45.9	43.0	48.8	45.9	51.5	44.5	6.0	0.0822
Smooth	67.3	61.9	65.0	58.6	63.1	61.0	5.3	**0.0323**
Dry	26.2	25.3	24.4	29.5	24.9	29.6	5.7	0.2710
Blemishes	2.6	3.5	4.0	3.1	4.2	6.4	2.7	0.0876
Glassiness	32.8	34.8	34.4	34.4	37.3	33.2	4.1	0.3088
Blackening / Greying	4.4	8.3	3.0	2.4	4.5	7.7	4.5	**0.0489**
Mottled	6.3	8.0	6.7	8.6	10.4	11.7	6.2	0.4724
Surface Disintegrating	5.7	11.4	10.6	12.1	10.3	10.8	5.3	0.2157
Cut the potato into 2								
Hardness on 1st Cut	32.1	30.4	33.9	32.9	32.7	30.5	4.3	0.4970
Texture/Mouthfeel								
Hardness on 1st bite	22.8	22.3	23.8	24.0	22.8	21.9	5.7	0.9565
Absorbent	47.6	49.8	44.8	47.2	47.2	44.0	4.9	0.3776
Waxy	25.9	21.8	26.9	20.9	24.7	27.6	6.0	**0.0491**
Floury	28.1	33.0	26.5	31.1	27.1	26.0	4.3	0.1339
Cloying	40.6	39.3	41.5	39.8	42.0	37.6	4.8	0.3676
Grainy	15.7	16.5	18.0	17.5	20.5	14.6	4.2	0.2146
Breakdown rate	44.4	40.0	44.7	40.2	40.6	45.1	5.7	**0.0294**
Flavour								
Overall flavour intensity	40.6	38.7	42.1	39.5	38.7	38.6	4.4	0.5302
Potato	33.0	32.0	32.5	32.9	30.3	30.1	2.8	0.1581
Sweet	17.6	18.8	23.0	13.8	19.1	21.5	4.2	**0.0014**
Fishy	0.5	0.3	0.3	0.7	0.8	0.4	0.7	0.6275
Savoury	2.8	0.5	1.6	1.9	1.6	1.1	1.9	0.2801
Earthy	22.9	19.0	17.7	21.4	21.7	20.2	5.4	0.4191
Sour	20.0	17.3	17.5	21.0	19.7	17.1	4.9	0.4635
Bitter	15.7	14.4	13.0	14.6	14.2	14.0	5.0	0.9393
Metallic	9.1	11.4	10.6	10.7	11.9	11.4	3.8	0.7432
Cabbage water	18.7	20.3	21.9	21.1	19.1	18.8	4.3	0.5554
Off	0.6	0.3	0.2	0.4	1.9	1.2	1.8	0.4037
Aftertaste								
Overall aftertaste intensity	29.2	29.5	30.5	29.3	31.0	27.1	2.6	0.1802
Potato	23.6	22.3	22.1	23.0	22.7	21.5	3.1	0.7016
Sweet	12.1	12.1	17.3	10.6	14.8	15.5	3.1	**0.0005**
Metallic	8.8	10.5	9.6	10.3	10.7	8.8	3.2	0.7209
Earthiness	15.5	13.2	12.2	15.3	15.8	14.1	4.2	0.1774
Sourness	18.9	18.2	17.3	20.0	18.2	16.2	4.3	0.5737
Bitter	14.5	14.7	14.5	14.7	15.8	13.1	2.6	0.8977
Afterfeel								
Astringent	32.7	32.6	29.6	34.1	32.2	34.2	3.5	0.1149
Mouthcoating	22.9	25.2	23.7	26.2	23.0	24.8	2.9	0.1676
Irritant	3.6	4.3	4.6	5.0	5.2	3.8	1.9	0.4565

HSD = Least Significant Differences, products with a difference in mean score higher then the LSD are significantly different in the represented attribute at the 5% significance level.

NS = No significance difference at 95% confidence level

TABLE A33: ESTIMA POTATO PROFILING (1)

	Untreated			Treated				
	Ambient	**1.5**	**4.5**	**Ambient**	**1.5**	**4.5**	**HSD**	**P Value**
Aroma								
Overall aroma intensity	35.6	37.5	37.1	38.8	35	35.2	4.8	0.1438
Potato	26.1	24.8	25.4	26.9	27.5	26.2	3.9	0.3681
Fishy	3.2	3.3	3.4	3.1	1.9	1.6	2.8	0.2403
Savoury	2	2.3	4.8	3.9	3	1.3	3.9	0.0968
Earthy	16.6	16.5	13.9	18.4	15.2	13.8	5.8	0.1633
Cabbage water	20.2	21.1	19.7	19	16.4	19.6	5.6	0.2435
Off	1.8	3.4	3.2	4.3	1.8	0.9	5.1	0.3843
Appearance								
Colour	52.5	56.1	56.3	58.2	55.7	58.8	6.1	0.0558
Smooth	68	66.8	67.6	71.1	64.7	70.2	6.3	0.0516
Dry	22.2	23.6	21.3	22.1	24.3	21.3	4.6	0.2954
Blemishes	4.4	5.1	5.5	6.4	9.3	4.5	6.8	0.3049
Glassiness	31.4	30.5	32.5	33.4	31.2	30.9	4.5	0.4287
Blackening / Greying	2	3	1.8	5.7	7.9	6	6.4	**0.0331**
Mottled	4.9	3.8	4	5.2	10.2	7.6	5.6	**0.0078**
Surface Disintegrating	5.4	6.6	4	3.4	5.8	4.2	3.6	0.0961
Cut the potato into 2								
Hardness on 1st Cut	28.4	28.9	27.2	28.6	33.6	30.6	5.2	**0.0098**
Texture / Mouthfeel								
Hardness on 1st bite	16.3	17.3	16.7	17.2	21.8	14.9	4.5	**0.0013**
Absorbent	41.4	38.9	37.2	39.9	36.7	33	8.0	0.0551
Waxy	22.9	26.8	21.5	23.9	26.4	29.7	7.7	**0.0319**
Floury	23.6	21.5	18	19.4	19.1	13.1	9.1	**0.0303**
Cloying	40.4	35.2	35.8	36	32.5	31.1	7.6	**0.0141**
Grainy	13.8	15.7	11.6	14.6	15.6	12.5	4.5	**0.0455**
Breakdown rate	44.8	44.8	47.3	46.3	50.1	52.3	7.2	**0.0163**
Flavour								
Overall flavour intensity	38.9	40.1	41	40	39.6	39.9	4.8	0.8924
Potato	28.7	29.1	28.2	30.2	29.2	28.2	3.7	0.6017
Sweet	19.1	20.6	26.4	21.6	24.5	26.9	6.3	**0.0017**
Fishy	1.2	1	0.6	1.4	0.4	0.7	1.8	0.5336
Savoury	1.4	0.8	1.4	1.4	0.7	0.9	1.6	0.5828
Earthy	20	17.4	15.7	19.3	15.4	15.4	5.2	**0.0282**
Sour	20.4	18.9	20.1	19.1	16.5	17.1	6.6	0.4498
Bitter	14.9	16.4	16.5	16.2	14.4	13.6	4.6	0.3114
Metallic	13.8	13.6	11.9	12.9	12.2	10.2	4.8	0.2739
Cabbage water	19.7	20.1	18.3	19.7	19.5	21	4.6	0.6736
Off	0.9	1.1	1	0.8	1.2	0.3	2.1	0.8674
Aftertaste								
Overall aftertaste intensity	29	28.7	31.4	30.6	28.9	29.1	4.6	0.4167
Potato	20.1	19.8	21.3	21.2	20.4	20.3	2.8	0.5792
Sweet	14.3	13.5	18.5	14.9	16.7	19.8	4.5	**0.0004**
Metallic	13.1	10.9	11.8	11.8	10.6	9	4.8	0.1923
Earthiness	12.9	11.1	10.7	12.5	11.8	10.5	3.5	0.2420
Sourness	21.8	18.8	21.5	21.5	17.3	16.8	5.7	**0.0272**
Bitter	16.4	15.6	19.4	19.2	15.5	14.3	5.1	**0.0221**
Afterfeel								
Astringent	29.8	26.5	29.1	29.5	25.3	26.5	5.0	**0.0405**
Mouthcoating	22	20.3	22.1	22.8	18.4	18.6	3.5	**0.0006**
Irritant	6.2	6	6.5	6.2	4.4	4.3	3.3	0.1877

HSD = Least Significant Differences, products with a difference in mean score higher then the LSD are significantly different in the represented attribute at the 5% significance level.

NS = No significance difference at 95% confidence level

TABLE A34: MARFONA POTATO PROFILING (1)

	Untreated			Treated				
	Ambient	1.5	4.5	Ambient	1.5	4.5	HSD	P Value
Aroma								
Overall aroma intensity	35.7	35.8	36.5	37	36.3	35.8	4.9	0.9623
Potato	27.3	26.4	26.1	25.6	25.2	24.8	4.7	0.6621
Fishy	2.2	2.6	1.4	2.5	3.2	1.4	2.3	0.1723
Savoury	3.3	2.4	3.5	3.5	1.9	2.2	3.8	0.6458
Earthy	13.3	14.6	16.3	16.3	13.7	13.8	5.7	0.4739
Cabbage water	18.1	18.9	19.7	22.5	19.3	14	7.8	0.0679
Off	1.5	1.5	0.8	1.9	0.4	4.7	4.4	0.0901
Appearance								
Colour	38.7	35.3	36.2	36.3	36.9	31.9	7.3	0.1489
Smooth	40.1	38	44	43.5	46.2	39.7	11.6	0.2839
Dry	39.2	44.7	33.9	36	33.7	39.1	9.6	**0.0127**
Blemishes	5.7	2.5	1.3	4.1	4.5	4.5	4.9	0.1137
Glassiness	27.8	29.6	29.7	28.2	28.7	29.1	5.9	0.9161
Blackening / Greying	2.1	1.8	2.3	1.6	1.8	4.2	4.2	0.4989
Mottled	11.9	12.2	12.8	12.7	11.2	14.7	7.4	0.8057
Surface Disintegrating	30.6	32	30.3	27.8	23.9	28.9	13.3	0.5513
Cut the potato into 2								
Hardness on 1st Cut	28.2	26.9	26.7	26.4	29.4	30.8	6.2	0.2558
Texture								
Hardness on 1st bite	17.3	13.5	17.4	16.5	18.3	21.1	6.0	**0.0217**
Absorbent	54.9	62.5	55	56.2	55.8	58	9.9	0.2096
Waxy	10.2	7.5	10.9	9.3	10.9	11.5	7.3	0.6322
Floury	44.3	52.5	43	48.3	43.4	50	9.8	**0.0259**
Cloying	43.5	50.4	40.2	46	42.3	46.2	9.9	0.0574
Grainy	20.4	21.9	18.3	18.4	19.3	21.9	5.6	0.1923
Breakdown rate	47.8	44.5	49.1	43.6	42.8	44.3	7.8	0.1209
Flavour								
Overall flavour intensity	38.5	38.1	38.4	38.3	40.4	37.8	5.1	0.7135
Potato	28.9	29.2	30.8	29.5	30.8	27.9	4.4	0.3631
Sweet	7.9	8.2	10.8	7.1	10.1	9	5.3	0.3120
Fishy	1.6	0.3	0.6	0.3	0.6	1	1.4	0.1088
Savoury	2.2	3.1	1.7	2.5	2.7	2.3	2.1	0.4879
Earthy	14.8	14.3	16.7	18.4	13.8	14.6	5.2	0.0917
Sour	21.3	23.1	20.2	24.6	20.7	18.5	6.3	0.0832
Bitter	14.7	12.3	12.3	15	14	13.7	3.7	0.1441
Metallic	11	11	11.2	14.2	13.3	11.2	3.8	**0.0434**
Cabbage water	16.2	15.4	17.6	17.7	17.3	11.3	6.2	**0.0292**
Off	0.7	0.3	0.3	0.3	0.6	4.5	5.1	0.1079
Aftertaste								
Overall aftertaste intensity	30.1	30	30.1	30.3	30	29.4	3.8	0.9907
Potato	21.1	21.4	22.3	22.2	21.3	20.5	4.5	0.8356
Sweet	5.2	6	7.1	5.2	5.5	5.3	3.8	0.6304
Metallic	11.8	12.3	10.2	11.7	11.1	9.5	3.7	0.2273
Earthiness	10	9.6	11.8	12.1	9.6	9.6	3.7	0.1393
Sourness	20.6	19.3	18.3	21.8	22.1	18.5	5.5	0.1782
Bitter	15.8	13.1	14.8	16.2	15	13.4	3.8	0.1033
Afterfeel								
Astringent	31.2	31.5	30.5	30.4	31.6	30.3	4.7	0.9449
Mouthcoating	28	30.2	25.3	28	27.4	27.5	7.5	0.5887
Irritant	7.1	5.2	5	6	6.2	5.8	2.7	0.2812

HSD = Least Significant Differences, products with a difference in mean score higher then the LSD are significantly different in the represented attribute at the 5% significance level.

NS = No significance difference at 95% confidence level

TABLE A35: MARIS PIPER POTATO PROFILING (1)

	Untreated			Treated				
	Ambient	**1.5**	**4.5**	**Ambient**	**1.5**	**4.5**	**HSD**	**p value**
Aroma								
Overall aroma intensity	40.3	40.5	41.3	43.8	42.4	42.1	5.3	0.4085
Potato	29.5	31.0	30.4	32.0	32.0	30.9	5.0	0.6930
Fishy	2.8	1.0	1.5	2.2	2.0	3.1	3.5	0.4850
Savoury	1.0	0.6	0.8	0.8	0.5	1.2	2.2	0.9534
Earthy	14.2	18.0	17.7	17.1	17.1	13.9	6.7	0.2999
Cabbage water	19.5	15.3	18.7	16.4	17.6	18.9	7.0	0.4692
Off	0.1	0.1	0.9	0.1	0.1	0.1	1.1	0.1246
Appearance								
Colour	43.4	45.4	41.2	46.1	43.3	44.9	5.5	0.1227
Smooth	66.6	67.4	65.0	65.7	67.8	66.7	7.8	0.9059
Dry	27.3	26.0	29.2	26.0	25.6	25.6	6.1	0.4845
Blemishes	4.3	6.5	4.4	3.6	4.3	3.7	3.7	0.2250
Glassiness	23.2	24.4	23.4	26.1	24.4	26.4	4.8	0.2710
Blackening / Greying	5.5	7.8	7.7	3.6	3.4	3.0	5.9	**0.0481**
Mottled	8.9	6.3	7.0	6.9	8.3	5.8	4.9	0.4197
Surface Disintegrating	10.3	7.2	10.0	9.3	6.9	6.7	5.1	0.1311
Cut the potato into 2								
Hardness on 1st Cut	30.7	32.7	35.3	31.1	30.9	29.1	6.7	0.1366
Texture								
Hardness on 1st bite	21.3	20.1	21.4	21.4	19.5	18.5	6.2	0.6651
Absorbent	45.7	47.5	46.7	40.2	42.8	43.9	8.7	0.1479
Waxy	18.0	18.5	23.8	23.0	20.3	20.9	10.3	0.4848
Floury	35.7	39.0	34.3	27.3	33.0	31.6	11.2	0.0770
Cloying	37.1	39.3	39.0	35.3	32.2	34.0	6.9	**0.0193**
Grainy	19.0	21.5	19.6	19.8	18.8	15.6	7.0	0.2636
Breakdown rate	43.1	42.5	42.1	46.9	47.0	50.1	6.0	**0.0007**
Flavour								
Overall flavour intensity	39.0	40.9	39.4	40.3	39.9	41.7	5.0	0.6439
Potato	31.2	31.9	31.4	32.8	31.4	32.8	4.9	0.8591
Sweet	14.8	16.0	18.9	19.3	17.6	19.6	7.3	0.2997
Fishy	0.5	0.4	0.1	0.3	0.1	0.3	0.7	0.5867
Savoury	0.7	0.4	0.4	0.4	0.4	0.9	1.3	0.7265
Earthy	14.8	15.6	13.5	14.9	14.5	13.1	5.4	0.7416
Sour	13.4	11.8	12.8	11.8	13.6	13.3	5.1	0.8030
Bitter	6.9	8.9	10.5	9.6	8.5	9.3	4.1	0.2076
Metallic	5.8	5.9	7.0	6.4	5.3	6.5	3.1	0.6911
Cabbage water	14.8	13.7	13.8	11.9	15.4	18.5	5.8	**0.0381**
Off	0.0	0.1	0.4	0.1	0.4	0.1	0.7	0.4109
Aftertaste								
Overall aftertaste intensity	28.5	30.7	31.1	31.0	30.0	32.3	4.1	0.1535
Potato	21.8	24.3	22.3	22.1	22.4	23.3	4.1	0.5017
Sweet	12.4	11.4	13.5	14.7	12.5	17.4	4.9	**0.0098**
Metallic	5.5	7.2	7.4	8.3	6.3	6.3	3.4	0.1878
Earthiness	8.9	10.5	8.6	9.1	8.5	8.5	3.9	0.6451
Sourness	13.6	13.9	13.2	12.9	14.2	13.5	4.6	0.9689
Bitter	8.6	10.2	11.3	10.6	9.3	11.2	4.7	0.4756
Afterfeel								
Astringent	33.6	34.3	37.0	34.0	34.4	32.3	4.3	0.0638
Mouthcoating	26.7	26.3	28.2	25.0	24.9	23.8	5.1	0.1611
Irritant	4.1	3.3	5.9	4.3	4.2	4.5	2.8	0.1890

HSD = Least Significant Differences, products with a difference in mean score higher then the LSD are significantly different in the represented attribute at the 5% significance level.
NS = No significance difference at 95% confidence level

TABLE A36: ESTIMA POTATO PROFILING (2)

	Untreated			Treated				
	Ambient	1.5	4.5	Ambient	1.5	4.5	HSD	P Value
Aroma								
Overall aroma intensity	40.8	41.3	42.4	40.8	38.6	38.1	5.8	0.2335
Potato	25.1	27.1	27.6	26.1	27.7	26.1	5.8	0.7508
Fishy	2.1	1.9	4.8	3.0	2.2	2.4	4.1	0.3254
Savoury	1.0	0.4	0.1	0.1	0.1	0.1	1.7	0.4718
Earthy	9.6	13.7	13.4	10.1	12.9	11.2	6.1	0.2184
Cabbage water	19.8	23.1	20.3	22.1	21.0	19.3	7.5	0.6697
Off	2.7	1.9	0.4	1.8	0.0	0.1	4.8	0.4581
Appearance								
Colour	46.2	53.7	52.9	53.3	49.4	52.2	6.7	**0.0106**
Smooth	74.4	72.9	71.2	69.8	72.1	74.8	6.1	0.1653
Dry	26.7	26.5	24.2	27.2	24.7	25.6	8.3	0.8748
Blemishes	2.6	3.8	3.1	8.7	5.4	7.5	4.7	**0.0008**
Glassiness	18.6	20.9	19.1	19.8	19.8	17.6	3.7	0.1589
Blackening/Greying	1.2	3.1	3.8	5.3	4.1	2.6	4.5	0.1571
Mottled	2.0	4.6	4.8	4.1	4.3	3.2	3.4	0.1350
Surface Disintegrating	3.2	4.2	4.2	5.6	3.0	4.0	4.3	0.5565
Cut the potato into 2								
Hardness on 1st Cut	20.5	23.6	24.5	24.4	26.1	26.6	5.3	**0.0201**
Texture								
Hardness on 1st bite	14.4	17.1	15.2	17.3	17.7	16.1	5.7	0.4905
Absorbent	34.2	32.5	34.2	37.1	34.3	35.9	9.0	0.7555
Waxy	25.9	25.3	22.5	24.8	27.0	25.4	8.1	0.7071
Floury	20.8	24.8	24.5	27.1	24.0	27.8	10.7	0.4519
Cloying	28.1	29.4	29.9	31.4	28.7	31.7	6.8	0.5707
Grainy	14.3	16.3	17.3	21.8	18.0	19.6	7.1	0.0572
Breakdown rate	51.4	51.3	49.7	47.2	46.5	46.3	7.5	0.1403
Flavour								
Overall flavour intensity	41.3	37.4	39.5	41.0	36.2	39.7	6.1	0.1098
Potato	27.2	24.8	27.2	27.9	27.6	28.3	5.2	0.4393
Sweet	21.1	19.8	18.8	19.2	21.5	25.4	8.0	0.1701
Fishy	0.5	0.1	0.7	0.7	0.2	0.1	1.5	0.6342
Savoury	0.2	0.3	0.0	0.4	0.3	0.1	0.6	0.4895
Earthy	12.2	12.4	11.4	12.8	11.9	12.7	5.1	0.9628
Sour	19.0	14.3	15.7	16.3	13.9	13.5	6.7	0.1644
Bitter	13.5	9.7	11.4	12.6	8.6	8.7	6.1	0.0985
Metallic	10.6	9.0	8.5	9.9	7.5	7.1	5.3	0.3569
Cabbage water	18.4	15.5	15.9	18.7	18.0	17.9	5.4	0.3770
Off	0.1	2.1	1.2	1.6	0.1	0.5	2.5	0.1160
Aftertaste								
Overall aftertaste intensity	30.9	28.2	28.2	30.8	27.9	28.7	4.6	0.1710
Potato	18.9	16.7	18.2	17.8	18.3	18.2	4.5	0.7941
Sweet	14.5	13.6	12.1	12.2	15.8	18.7	6.6	**0.0375**
Metallic	9.4	8.3	9.4	10.5	6.7	6.0	3.5	**0.0023**
Earthiness	8.8	8.4	8.0	7.4	8.2	7.8	3.8	0.9172
Sourness	20.3	16.1	17.6	18.4	16.1	14.7	5.9	0.0968
Bitter	13.9	13.3	13.5	15.8	12.8	10.8	4.9	0.1177
Afterfeel								
Astringent	31.1	32.4	31.4	34.2	32.6	32.9	4.6	0.4318
Mouthcoating	20.0	20.2	21.0	25.0	23.9	23.8	5.0	**0.0121**
Irritant	5.1	6.5	5.0	5.1	4.5	4.8	3.9	0.7186

HSD = Least Significant Differences, products with a difference in mean score higher then the LSD are significantly different in the represented attribute at the 5% significance level.

NS = No significance difference at 95% confidence level

TABLE A37: MARFONA POTATO PROFILING (2)

	Untreated			Treated				
	Ambient	1.5	4.5	Ambient	1.5	4.5	HSD	P Value
Aroma								
Overall aroma intensity	35.8	34.3	33.8	34.3	35.0	35.8	5.0	0.7629
Potato	26.7	25.2	26.0	25.0	25.4	25.7	5.5	0.9510
Fishy	3.1	3.3	2.2	3.8	1.4	3.3	3.8	0.4753
Savoury	0.1	0.8	0.1	0.1	0.3	0.1	0.9	0.1239
Earthy	14.6	11.2	14.5	12.8	14.5	10.7	5.0	0.0717
Cabbage water	16.1	12.7	14.9	15.4	13.4	14.9	5.7	0.5140
Off	0.0	0.1	0.1	0.1	1.3	0.1	1.6	0.1407
Appearance								
Colour	33.6	33.0	37.0	33.5	36.4	34.4	4.9	0.0919
Smooth	50.9	48.8	46.5	45.1	45.4	54.3	10.2	0.0694
Dry	37.3	39.8	42.8	40.9	43.9	39.7	8.6	0.2707
Blemishes	5.0	3.3	6.9	2.8	5.9	3.9	4.5	0.0728
Glassiness	18.4	19.6	22.0	18.4	20.3	20.1	6.2	0.5469
Blackening/Greying	2.6	2.9	4.0	1.6	4.6	2.8	4.2	0.3635
Mottled	9.3	13.4	12.8	12.9	17.3	13.1	9.0	0.2364
Surface Disintegrating	24.7	30.8	32.3	34.4	32.9	25.1	12.1	0.0875
Cut the potato into 2								
Hardness on 1st Cut	31.0	30.2	31.6	25.8	28.6	29.7	5.9	0.0682
Texture								
Hardness on 1st bite	17.4	15.1	17.9	14.2	13.4	16.2	5.2	0.0945
Absorbent	49.7	53.1	54.2	51.3	53.4	51.7	7.0	0.4589
Waxy	8.0	4.3	5.2	5.4	6.7	6.7	7.0	0.6777
Floury	51.5	53.1	55.3	54.0	53.7	51.9	9.0	0.8237
Cloying	40.6	45.9	44.4	44.9	46.7	41.3	7.4	0.0982
Grainy	24.0	25.9	22.8	21.7	23.7	24.2	6.3	0.4986
Breakdown rate	43.7	43.5	42.7	43.4	41.4	43.2	5.6	0.8531
Flavour								
Overall flavour intensity	37.1	35.6	34.3	34.9	35.2	36.6	4.4	0.4276
Potato	29.0	28.3	28.8	27.8	26.4	27.9	4.2	0.5412
Sweet	5.5	4.8	6.1	6.7	9.1	5.6	4.0	0.0511
Fishy	0.1	0.1	0.1	0.0	0.0	0.6	0.6	0.0699
Savoury	0.5	0.6	0.3	0.4	0.3	0.2	0.9	0.7470
Earthy	12.9	14.3	14.2	13.8	12.9	12.6	5.7	0.9137
Sour	21.8	18.4	18.6	20.5	20.7	18.0	5.5	0.2682
Bitter	13.6	13.9	12.9	14.1	14.1	12.2	5.0	0.8473
Metallic	9.5	8.6	7.5	10.5	9.1	8.2	4.8	0.5346
Cabbage water	12.0	10.6	9.9	13.3	11.5	9.1	5.5	0.2772
Off	0.6	0.5	1.1	0.0	1.0	0.1	1.6	0.2752
Aftertaste								
Overall aftertaste intensity	29.8	27.3	28.4	29.0	30.4	28.7	3.9	0.2475
Potato	20.5	20.0	20.4	21.1	19.5	19.3	4.3	0.8327
Sweet	2.7	2.4	3.5	2.8	4.5	3.8	3.6	0.5036
Metallic	9.0	8.0	8.1	9.4	9.5	8.6	4.0	0.8329
Earthiness	9.6	9.9	10.4	10.3	9.8	9.8	4.3	0.9935
Sourness	20.3	17.2	18.1	21.9	20.3	18.3	6.1	0.2170
Bitter	15.7	12.6	12.8	14.4	14.5	13.3	4.9	0.4277
Afterfeel								
Astringent	36.6	36.6	38.9	36.9	38.9	35.6	4.5	0.1887
Mouthcoating	32.1	32.0	31.2	31.4	32.8	29.9	5.4	0.6954
Irritant	7.1	6.8	4.9	6.1	8.0	8.2	3.5	0.0750

LSD = Least Significant Differences, products with a difference in mean score higher then the LSD are significantly different in the represented attribute at the 5% significance level.

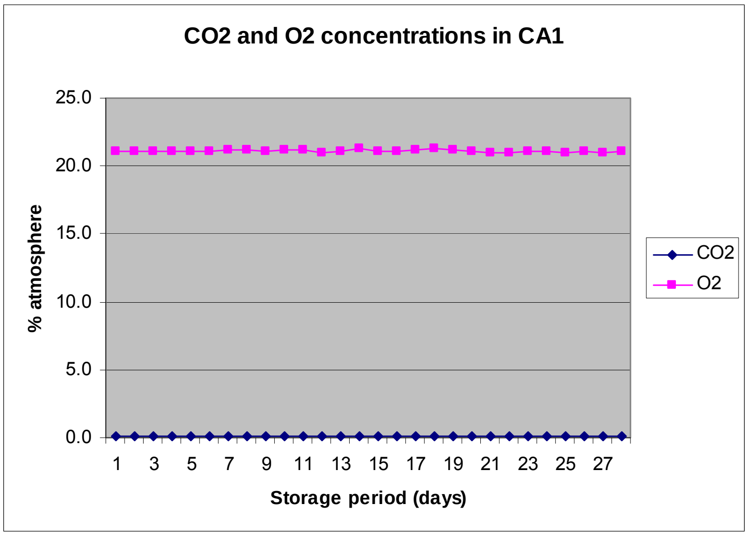
NS = No significance difference at 95% confidence level

TABLE A38: MARIS PIPER POTATO PROFILING (2)

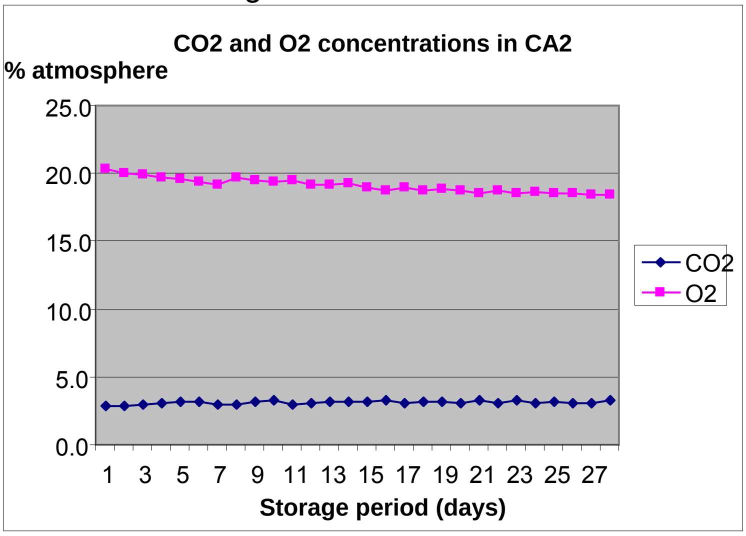
12. Appendix 1: Potato tuber infection by bacterial and fungal pathogens at different carbon dioxide incubation atmospheres.

12.1. Concentrations of carbon dioxide and oxygen over the course of the incubations.

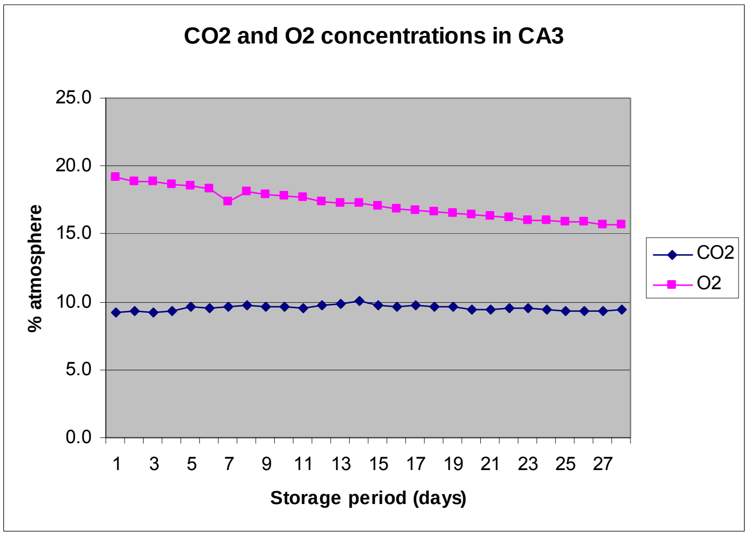
Chamber CA 1 target ambient CO2: CO2 and O2 concentrations during incubation



Chamber CA 2 target 3% CO2: CO2 and O2 concentrations during incubation



Chamber CA 3 target 10% CO_2: CO_2 and O_2 concentrations during incubation



12.2. Tuber peel sample preparation

- Completely peel potato tuber using peeler to cut ~2mm thick peel and weigh.
- with kitchen knife dice peel into ~5 mm pieces
- Add, with 2 volumes ice cold water, to 100 ml beaker.
- Leave temporarily on ice or in fridge until ready to process.
- Swirl all pieces and water into cut off plastic beaker~100 ml and macerate using Ultra Turrax PMX-279, @ 17,500 rpm for 30 sec. There is no significant temperature change at this speed for this length of time, max ~1°C/ min. The macerate is very uniform, no large lumps, but is variably frothy.
- Filter through nappy liner, or J cloth, into a 100 ml beaker.
- Swirl to mix filtrate, and completely fill a polystyrene 15 ml culture tube. Discard rest.
- Cap and incubate on ice 20 min to allow starch and other fine debris to settle.
- Remove 1 ml aliquot from near surface of liquid. Can take multiple aliquots if needed. 1 ml is equivalent to 0.5 g peel.
- Spin in microfuge 10K rpm, 10 min.
- Remove supernatant and freeze pellet -20°C or, better; proceed directly to Qiagen DNA extraction.

12.3. Real time PCR detection of *Pectobacterium carotovorum*

Primer sequences and information kindly provided by John Elphinstone, Fera. The real-time PCR assay with PEC primers and probes detects all pectolytic *Pectobacter*

and *Dickeya* spp. including *Erwinia chrysanthemi* and *Erwinia carotovora* subspecies *atroseptica*, *carotovora*, *betavasculorum*, *oderifera* and *wasabiae*.
The real time PCR assay with ECH primers and probe is specific for *Erwinia chrysanthemi* (*Dickeya* spp.) and detects all known biovars and pathovars with the exception of *E. chrysanthemi pv. paradisiaca* from Banana (now *Dickeya paradisiaca*).
The real time PCR assay with Eca primers and probe is specific for *Pectobacterium atrosepticum.* By use of all three sets of diagnostics, elimination defines the identity of the bacterial species.

PEC-1F	GTGCAAGCGTTAATCGGAATG
PEC-1R	CTCTACAAGACTCTAGCCTGTCAGTTTT
PEC-CSL_probe	CTGGGCGTAAAGCGCACGCA

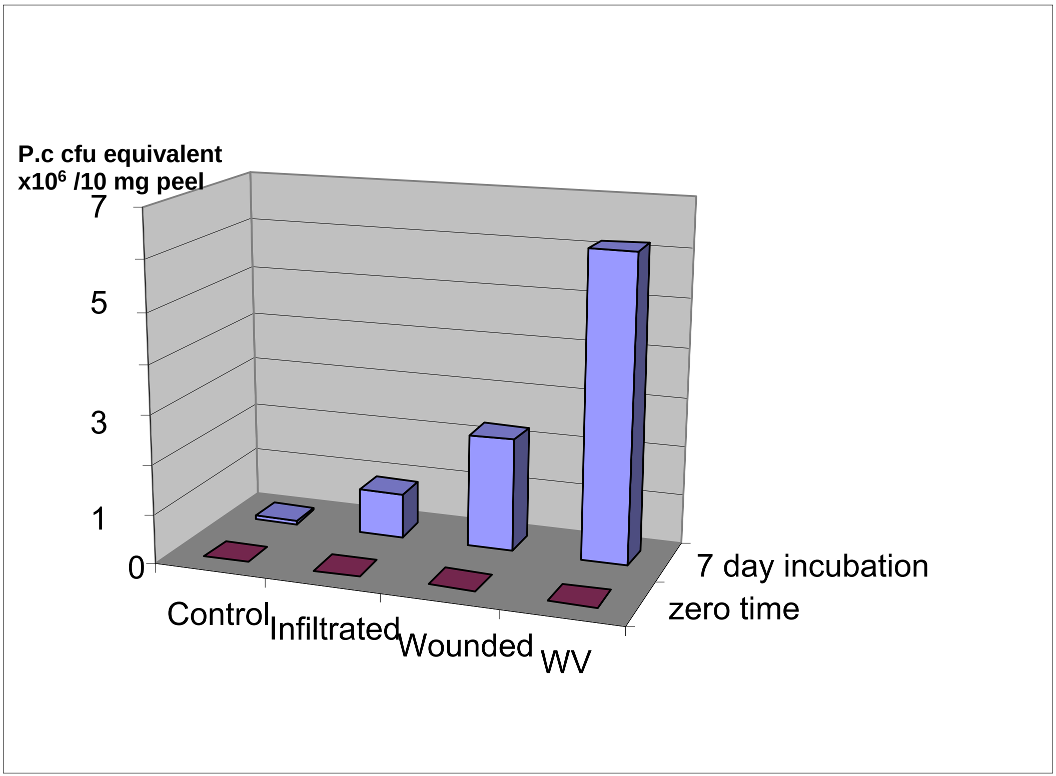
For Stratagene Mx 3005P PCR machine
12.5 µl Stratagene Master Mix
1 ul Pec Forward Primer (10 µM/ul)
1 up Pec Reverse Primer (10 µM/ul)
0.25 ul Pec Forward Probe (10 µM/ul)
Sample (1-2 µl)
Water to 25 µl
Run programme: Fast 2 Step,

12.4. *Pectobacterium carotovorum* infection standard curve

Prepare 1 ml serial dilutions of 108 cfu/ml suspension in water to create series 109 – 102 cfu/ml. 109 cfu created by combining sediments after 10K rpm, 10 min centrifugation of 10 ml 108 cfu/ml.
Spin in microcentrifuge 10K rpm, 10 min. Decant supernatant.
Either freeze pellet -20°C or better; proceed directly to Qiagen DNA extraction.

P.c suspension series	cfu in PCR assay, 2 ul sample
109 cfu	20000000
108 cfu	2000000
107 cfu	200000
106 cfu	20000
105 cfu	2000
104 cfu	200
103 cfu	20

12.5. *Pectobacterium carotovorum* infection under semi-anaerobic incubation conditions



12.6. *Fusarium sulphureum* and *Phoma exigua* infection under semi-anaerobic incubation conditions

	Potato tuber Number	Depth of infection (mm)	Width of infection (mm)
Control	1	21	4
	2	21	4
	3	24	4
	Average	22	4
P. exigua var foveata	1	25	12
	2	24	12
	3	36	53
	Average	28.3	25.7
F. sulphureum	1	47	37
	2	28	13
	3	26	47
	Average	33.7	32.3