Research Report

Use of ethylene and CIPC on processing varieties of potato 2013-2016

Ref: R464

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1. Summary

1.1. Aim

The aim was to investigate the effect, on commercial processing varieties, of ethylene and Isopropyl (3-chlorophenyl) carbamate (Chlorpropham, CIPC) on sprouting and fry colour.

1.2. Methodology

In the 2015/16 storage season, varieties were stored in boxes at 9ºC. A single CIPC application at intake, or continuous 10 ppm ethylene, or both were used. Samples were removed at two monthly intervals for eight months (six months in previous trials) and assessed for sprouting and French fry or crisp fry colour.

1.3. Key findings

Continuous 10 ppm ethylene suppressed sprout growth in all the varieties tested and to commercially acceptable standards for 6 months' storage for both Markies and Russet Burbank. Ethylene affected fry colour in many, but not all, varieties although did not generally affect commercial fry colour acceptability overall. In particular, the effect on Maris Piper, Markies and Russet Burbank was small and did not compromise commercial acceptable limits.

A combination of a single low dose application of CIPC with continuous 10 ppm ethylene, provided better sprout control, for all varieties at all sampling occasions, than either treatment alone. Sprouting was controlled to within commercially acceptable limits in most varieties to eight months' storage. The effects of combination treatment on fry colour were essentially those found with ethylene treatment alone. Maris Piper, for which fry colours were unaffected by ethylene, Markies (generally) and Russet Burbank were able to be stored under a combination of CIPC & ethylene with good sprout control and acceptable fry colours.

1.4. Practical recommendations

On the basis of this work some varieties, including Maris Piper, Markies and Russet Burbank, can be stored successfully under ethylene for six months with good sprout control and acceptable fry colours. Better control of sprouting was found with storage under CIPC & ethylene for six to eight months than with either product alone.

2. Experimental Section

2.1 Introduction

There is a need to provide alternatives to the currently commercially dominant sprout suppressant CIPC because of the threats to its continued use. AHDB is closely involved in developing a range of alternative strategies to CIPC usage to provide growers with a wider range of viable strategies if further restrictions on CIPC use were to be imposed in the future.

Ethylene has been successfully used with some GB varieties for sprout suppression by the fresh potato sector. However, not all varieties are sufficiently responsive to ethylene and its suitability as a sprout suppressant on any variety must be determined empirically. Previous work in this area has been carried out at Sutton Bridge Crop Storage Research (SBCSR) as part of the Link project LK09217 (Colgan *et al.* 2013) and which developed methods and partially screened some UK processing varieties for ethylene response.

Continuous application of ethylene (4-10 ppm) to potatoes during storage has been developed as an alternative to CIPC, as it inhibits the growth of sprouts once they have initiated (Prange *et al*. 1998). Ethylene has hence been used as an alternative to CIPC in the UK fresh marketed potato sector. This development was brought about through previous research funded by DEFRA (HH2114STF) and industry funded trials including those by Greenvale. Currently, over 150,000 tonnes of potatoes are treated with ethylene. However, an important constraint to ethylene use for sprout suppression is that of varietal variability in ethylene sensitivity. This requires most varieties need to be held at low temperature for effective sprout control. In addition to this, ethylene can induce increased respiration and sugar accumulation in some varieties at low temperatures. This would not be acceptable for processing varieties as sugar accumulation causes fried products to become unacceptably dark. Sugar accumulation also impacts on the increased potential to produce acrylamide, identified as a potential carcinogen, during potato processing.

The aim of this R464 trial was to identify varieties in which sprouting can be well controlled by ethylene without significant deleterious effect on fry colour. A further aim was to build on the results of a previous AHDB Potatoes project (R441) which investigated the effect on commercial processing varieties of combination treatment of ethylene and CIPC on sprouting and fry colour. This demonstrated a potential synergy between the two treatments with respect to sprout control.

2.2 Materials and methods

Materials and methods for previous year's trials may be found in the relevant year report.

Crops, treatments and experimental design

In 2015, seven processing varieties were supplied for the trial. Maris Piper and Royal [*Sacker Potatoes Ltd*]; Markies, Ramos and Russet Burbank [*McCain Foods GB Ltd*] and Olympus and Russet Burbank [*Spearhead International Ltd*].

Netted samples of each were buried approximately three tubers down in 1-tonne pallet boxes of Russet Burbank divided between three 9.0 °C experimental stores. Two were treated with single doses of chlorpropham (CIPC), at 9 and 16 grams per tonne respectively, both followed up with ethylene maintained at a target concentration of 10 ppm. The third store represented current best practice and was treated with CIPC only, at 12 g/tonne per treatment, as required to control sprouting. The experimental design was an unreplicated comparison of treatments with variation measured by four in-store replicates.

Store set up and control

The 12-tonne capacity Controlled Environment Rooms were identically configured for positive ventilation. One tonne boxes were stacked in three columns of four, tightly against a four-slotted plenum chamber. Air discharged from the plenum was blocked at ground level and at the bottom of the third box up. Alternate pallet apertures were blocked at the opposite end to force air through the crop. Due to limited trial space, each replicate was assigned a height level. Replicate 1 samples were located in the lower level and then in sequence until replicate 4, at the upper level. Net location within a three box level was completely randomised. Air was recirculated through a duct at the bottom of the store for refrigeration or heating as necessary. Stores were humidified by compressed air driven water atomiser.

Pull down and applications

At the beginning of storage, crop temperatures were pulled-down at a rate of 0.5 °C per day until the holding temperature of 9.0 C (± 0.5 °C). Humidification was then enabled at 95% RH (± 5%).

CIPC [*Pro-long*, MAPP 14389] was applied as a hot fog, using a *Swingfog SN50* [*Motan*] applicator, to pre-loaded 12-tonne capacity box stores. Initial applications were made on 6th November 2015. The stores were fogged through a port in a personnel door accessing a corridor beside the stack of potatoes. An auxiliary fan [*Multifan TB4E50*, *Vostermanns Ventilation BV*] was used to immediately draw fogged air into the plenum and force it through the crop at the lowest setting of 0.45 m^3/s for 6 hours. After this period the stores were ventilated by opening the front door for 5 to 10 minutes, resealed and returned to automatic temperature control. The CIPC only store was retreated on 18th December 2015 and 9th March 2016. For the second application only, the slot blocking configuration was reversed to promote even CIPC distribution.

Ethylene treatments followed shortly after CIPC application on 9th November 2015. Ethylene catalytic generators [ICA75, Restrain Company Ltd] fuelled by ethanol were used to provide a ramped, daily, manual introduction of ethylene at progressively increasing concentrations: from 0 to 1 ppm in increments of 0.1; 2 to 4 ppm in increments of 1; and 6 to 10 ppm in increments of 2. During the ramp the store was vented to zero every day immediately before reintroducing ethylene at the prescribed concentration. As the generator was designed for a large scale store, fuel was diluted to 20 % with deionised water and the flow rate initially set to the minimum of 0.1 litres per day. On 25th November 2015, automatic ethylene generation was initiated at 10 ppm. The generator was used to both monitor and record ethylene levels.

Assessments

Assessments were conducted at intake and after 2, 4, 6 and 8 months of storage. For each sample the longest sprout length was measured on all tubers of a 25 potato sub-sample. Fry colour was measured for potatoes processed as crisps for Olympus & VR808 and chips (French fries) for Maris Piper, Markies, Ramos, Royal & Russet Burbank.

For crisping, 300 g of slices between 1.22 and 1.47 mm thick were taken from 30 mechanically peeled tubers and washed in water for 45 seconds. Each sample was then fried for 3 minutes in oil heated up to 177 °C at the start of frying. After frying, the sample was weighed and then crisps with defects (a dark discolouration larger than a 5 mm diameter circle) removed and weighed. The remaining blemish-free sample was then assessed objectively three times using a HunterLab D-9000 colour quality meter fitted with a D25-L optical sensor [*Stotto Group, Mountsorrel, Leics.,UK*].

Chips were processed as single 3/8th inch square longitudinal sections from each of 20 sound tubers and fried for 90 seconds in oil heated up to 190 °C at the start of frying. The fry colour of individual strips was assessed subjectively by comparison with a USDA standard colour chart [*Munsell Color, Baltimore, Maryland, USA*] under standard artificial white light. The USDA assessment scale used for assessing chips (light to dark - 000, 00, 0, 1, 2, 3 & 4) was linearized 1 to 7 (SBCSR scale) and reported as a mean. Scores of 1 to 3 are good; scores of 4 and 5 acceptable and higher scores rejected.

Statistical analysis

The statistical significance threshold was set at 5% or less and a parametric Analysis of Variance (AnoVA) was used. All statistical analyses were compiled on SPSS software, version 22.0. Graphs were additionally compiled in MS Excel from resulting descriptive statistics.

For all 7 varieties, ANOVA had 2 factors:

- Sampling occasion (4 periods)
- Sprout suppressant (3 levels).

The response variables per sample number per variety were:

- Mean Longest Sprout [4 replicates of 25 tubers]
- % Fry Defects and Hunter Mean L for the Crisping varieties VR808 and Olympus.
- Chip Score Index for varieties Maris Piper, Markies, Ramos, Royal and Russet Burbank.

Where Levene's test for 'equality of variances' found unequal variances in the groups being tested (P<0.05), log^e transformation was applied to data values to reduce inequality. Post-hoc Bonferroni comparisons were applied to investigate significant differences ($P<0.05$) in the ANOVA.

2.3 Results 2015-16

Sprouting

The mean longest sprout length per tuber (mm) is shown in Table 1. Sprouting up to 3mm would be considered good for processing crops. Between 3 and 10 mm might be acceptable but lengths in excess of this would normally be rejected. Variation was high particularly with CIPC in the later sampling occasions due to high sprouting pressure combined with low dose and imperfect distribution.

The results of sprouting for each variety under the different sprout control regimes are shown in Table 1 and represented graphically in annex Figures 1 and 2. Sprouting increased with storage duration. Sprouting in Maris Piper and Olympus was less than 3mm for the duration of the trial under with each of the three treatments. Ramos and VR808 were rather less well controlled, although the longest mean sprout length just above the 10mm maximum applied in this trial was found in only one treatment/sampling occasion, 11.57mm and 6 months (Ramos) and 12.87mm and 8 months (VR808).

For all varieties and for every sampling occasion, except Ramos at six months storage, the lowest mean sprout length was observed with CIPC 16g/t + ethylene with statistically significant results for all varieties except for Maris Piper and Ramos.

Sprout length with CIPC 9g/t + ethylene was generally somewhat less than with CIPC alone on 18/28 occasions and as an overall grand total Table 1, but the results were not statistically significant except for the varieties Markies and Russet Burbank.

Table 1. Mean Longest Sprout (mm) per treatment of by variety and sampling occasion.

			Mean sprout length (mm) per sprout suppressant		
Process type	Variety	Sampling occasion (months)	CIPC best practice	CIPC 9g/t + ethylene	CIPC 16g/t + ethylene
French fry	Maris Piper	2	1.9	1.96	1.56
		4	2.22	1.98	1.08
		6	1.54	1.56	0.81
		8	1.05	1.44	1.03
	Markies	2	0.61	0.09	0.09
		4	1.13	0.21	0.1
		6	1.91	1.2	1.11
		8	10.07	3.5	3.19
	Ramos	2	1.25	0.74	0.54
		4	7.27	3.19	2.01
		6	6.12	11.57	6.21
		8	9.53	9.59	5.63
	Royal	2	2.8	1.93	1.82
		4	6.37	2.48	1.88
		6	6.6	5.33	2.26
		8	2.74	7.66	2.12
	R. Burbank	2	0.1	0.01	0.07
		4	1.41	0.57	0.17
		6	3.65	1.5	1.21
		8	8.13	2.19	1.49
Crisp	Olympus	2	0.08	0.01	0.01
		4	1.04	1.16	0.17
		6	1.28	2.53	0.42
		8	1.31	1.81	0.78
	VR808	2	3.66	1.62	1.78
		4	7.28	3.59	2.85
		6	5.64	7.13	4.37
		8	12.87	8.09	4.09
Overall average			3.91	3.02	1.74

Table 2. ANOVA of sprouting results showing the significance of suppressant treatment, sampling occasions and interaction.

Variety	Sampling Occasion (SO)	Suppr-essant	SO and Suppr-essant	CIPC 16g/t + ethylene vs. CIPC 9g/t + ethylene	CIPC 16g/t + ethylene vs. CIPC best practice	CIPC 9g/t + ethylene vs. CIPC best practice
				Bonferroni test comparison		
M. Piper#	NS	*	NS	*	NS	NS
Markies	***	***	NS	NS	***	***
Olympus	***	***	*	***	***	NS
Ramos	***	*	*	*	NS	NS
Royal	NS	**	NS	*	*	NS
R. Burbank	***	***	NS	NS	***	***
VR808	***	**	NS	NS	**	NS

NS: Non-significant result (P>0.05). Significant results * (P<0.05), ** (P<0.01), *** (P < 0.001).
No data transformation.

Effect of suppressant treatment on crisp fry colour

Crisp fry colour was assessed by Hunter Lab measurement and results are shown in Table 3. Values greater than L 59 are considered commercially good, between L 59 and L 49 crisps may be acceptable but less than L 49 would be rejected. In the assessment method used in the trial a crisp below L 49 would be taken out of the sample as a reject and the remainder assessed. However, when as much as almost half the sample is missing, there is not enough sample left for assessment.

Treatment with ethylene resulted in slightly darker fry colours with an average higher Hunter L score of between 2.4 and 3.3 in its absence (Table 3). Olympus treated with CIPC alone provided acceptable fry colours to 6 months storage but only to 4 months storage when ethylene was included in the treatment. However, there were no statistically significant differences in colour value between the treatments (Table 4). For VR808, there were statistically significant differences in colour value between treatments. Acceptable fry colours were achieved to 8 months storage with CIPC alone and to 6 months storage when ethylene was included with the treatment.

Table 3. Mean Hunter L values per suppressant by variety and sampling occasions

		Sprout suppressant		
Variety	Sampling occasion (months)	CIPC best practice	CIPC 9g/t + ethylene	CIPC 16g/t + ethylene
Olympus	2	65.06	61.30	61.20
	4	64.68	63.18	62.44
	6	61.83	58.64	58.15
	8	54.04	-	-
VR808	2	65.92	63.41	65.36
	4	66.12	66.04	63.69
	6	67.29	64.19	61.68
	8	60.77	56.93	57.00
Overall average (not including Olympus 8 month values)		64.52	61.95	61.36

- values lower than Hunter L 49.

Table 4. ANOVA and post-hoc test of mean Hunter L values by suppressants, sampling occasions and interactions

Variety	Sampling Occasion	Suppr-essant	SO and Suppr-essant	CIPC 16g/t + ethylene vs. CIPC 9g/t + ethylene	CIPC 16g/t + ethylene vs. CIPC best practice	CIPC 9g/t + ethylene vs. CIPC best practice
				Bonferroni test comparison		
Olympus#	***	*	NS	NS	NS	NS
VR808#	***	***	*	NS	***	***

NS: Non-significant result (P>0.05). Significant results * (P<0.05), ** (P<0.01), *** (P < 0.001).
data analysed following natural logarithm transformation.

Crisp defects

Table 4 shows the percentage weight of crisps with defects. Less than 5% defect would be considered commercially low and acceptable and greater than 15% unacceptable.

Generally treatment with ethylene resulted in higher % fry defect scores (Table 4) storage although these increases were not necessarily of commercial significance. There were two instances, VR808 at 2 and 6 months, when fry defect values were commercially unacceptable where ethylene was included in the treatment but where the ethylene-free treatment was acceptable.

There were no statistically significant differences in the levels of fry defects between the treatments CIPC 16g/t + ethylene and CIPC best practice. However, there were statistically significant differences between CIPC 9g/t + ethylene and CIPC best practice (Table 5).

Table 4. Mean % fry defects per suppressant by variety and sampling occasion

		Sprout suppressant		
Variety	Sampling occasion (Months)	CIPC best practice	CIPC 9g/t + ethylene	CIPC 16g/t + ethylene
Olympus	2	0.74	3.82	1.59
	4	0.32	1.86	1.23
	6	2.15	4.20	0.39
	8	39.64	100.00	100.00
VR808	2	2.48	7.72	1.84
	4	1.46	2.48	0.80
	6	1.20	5.86	5.13
	8	8.73	34.64	41.50
Overall average		7.09	20.07	19.06

Table 5. ANOVA and post-hoc test of fry defect values by suppressants, sampling occasions and interactions

Variety	Sampling Occasion	Suppressant	SO and Suppressant	CIPC 16g/t + ethylene vs. CIPC 9g/t + ethylene	CIPC 16g/t + ethylene vs. CIPC best practice	CIPC 9g/t + ethylene vs. CIPC best practice
				Bonferroni test comparison		
Olympus	***	**	NS	NS	NS	**
VR808	***	*	NS	NS	NS	*

NS: Non-significant result (P>0.05). Significant results * (P<0.05), ** (P<0.01), *** (P < 0.001).

French fry colour score

The USDA assessment scale used for assessing French fries (light to dark - 000, 00, 0, 1, 2, 3 & 4) was linearised to a 1 to 7 scale (SBCSR score) as shown below (Table 6). A score up to 3.9 would be considered good, 4 to 5.9 borderline, whereas higher scores would be rejected. Mean French fry colour scores are shown in Table 7.

Overall treatment with ethylene resulted in slightly darker (15%) as a total average fry score (Table 7) although only for Markies were statistically significant differences found between treatments with and without ethylene (Table 8).

Table 6. Chip scale conversion table

SBCSR	1	2	3	4	5	6	7
USDA (standard)	000	00	0	1	2	3	4

Table 7. Mean chip fry colour score values per suppressant, by variety and sampling occasion.

		Sprout suppressant		
Variety	Sampling occasion (months)	CIPC best practice	CIPC 9g/t + ethylene	CIPC 16g/t + ethylene
Maris Piper	2	3.48	2.88	3.10
	4	3.09	3.13	3.29
	6	3.40	3.51	3.56
	8	4.63	5.40	5.48
Markies	2	2.20	3.14	2.48
	4	1.50	2.96	2.59
	6	1.78	3.14	2.80
	8	2.58	4.08	3.91
Ramos	2	1.58	1.44	1.41
	4	1.24	1.91	1.31
	6	1.79	2.56	2.98
	8	4.88	4.66	4.93
Royal	2	3.03	3.00	2.95
	4	2.65	3.20	2.89
	6	2.88	3.45	3.63
	8	4.71	5.14	5.55
Russet Burbank	2	3.29	3.40	3.18

	4	2.98	3.40	3.10
	6	3.04	3.26	3.21
	8	3.55	3.48	3.42
Overall average		2.91	3.36	3.29

Table 8. ANOVA and post-hoc test of Chip Score values by suppressants, sampling occasions and interactions.

Variety	SO	Suppr-essant	SO and Suppr-essant	CIPC 16g/t + ethylene vs. CIPC 9g/t + ethylene	CIPC 16g/t + ethylene vs. CIPC best practice	CIPC 9g/t + ethylene vs. CIPC best practice
				Bonferroni test comparison		
Maris Piper	***	NS	NS	n/a	n/a	n/a
Markies	***	***	NS	*	***	***
Ramos	***	NS	*	n/a	n/a	n/a
Royal	***	*	*	NS	NS	NS
R. Burbank	NS	NS	NS	n/a	n/a	n/a

NS: Non-significant result (P>0.05). Significant results * (P<0.05), ** (P<0.01), *** (P < 0.001).

Otherwise, darker colours induced by ethylene treatment were not necessarily of commercial significance. There was only a single instance, Markies at 8 months, when fry colour values were commercially unacceptable when ethylene was usedd and where the ethylene-free treatment was commercially acceptable. With the exception of Russet Burbank, longer stored tubers had darker fry colours and, for Maris Piper, Ramos and Royal, these were commercially unacceptable at 8 months.

2.4 Discussion for overall trials 2013-16

An objective of the overall project was to understand the effect of ethylene on processing quality, over short and long term storage, and whether the combined use of ethylene and CIPC could provide an alternative solution for sprout control.

Ethylene treatment

Previous research (Prange *et al*. 1998, Colgan *et al.* 2013) and previous years trials within this project (R464) demonstrated that continuous application of ethylene at 4-10 ppm to potatoes inhibits the growth of sprouts. The degree of sprout inhibition was in the main determined varietally with sprouting in some varieties e.g. Maris Piper being relatively poorly controlled and in others e.g. Markies or Russet Burbank very well controlled (Colgan *et al* 2013. Annex: Table 1).

Apparently independent from the effect on sprouting was an effect of ethylene on sugars and, of commercial significance, fried potato colour (Prange *et al*. 1998, Rees *et al.* 2014 LK09127 and previous year's trials within this project (R464)). Ethylene treatment may darken the fry colour and so reduce the commercial acceptability of the product. Again there was a varietal component to the effect with some varieties e.g. Maris Piper being essentially unaffected and others e.g. Hermes significantly affected.

Changes in reducing sugar content were found for the varieties under the different treatments (Colgan et al. 2013). The lowest reducing sugar contents were generally found following treatment with CIPC alone and, generally, ethylene increased the content. However, levels of the different sugars were similar in ethylene treatments and untreated controls. The relationship between sugar content and fry colour is not straightforward, as discussed by Burton (1989) and Colgan *et al.* (2013). For example, the increased reducing sugars found in ethylene-treated Maris Piper compared with treatments using CIPC alone did not result in a discernible effect on fry colour. Sugar levels did not discernibly increase with sprouting. Very similar sugar levels were found under both ethylene and CIPC & ethylene treatments for Hermes and Saturna (for all storage durations) or Maris Piper (up to four months storage) despite extensive sprouting occurring under ethylene alone. It is probable that any additional sugars mobilised were rapidly used to fuel growth.

Overall, the trials demonstrated that ethylene alone could provide an alternative sprout suppression strategy but its suitability was variety specific. Those for which it was suitable included the important French fry varieties Markies and Russet Burbank.

Ethylene & CIPC treatment

R441 (2010-11, 2011-12)

During the two years of a previous trial (R441; 2010-11, 2011-12) a single application of 21 ppm CIPC was used, the then maximum permitted single dose, at the beginning of storage. For combined treatment, ethylene was gradually introduced to and maintained at 10 ppm. The varieties assessed were Cabaret, Hermes, Maris Piper, Markies, Russet Burbank, Saturna and Verdi.

For both years, the CIPC and CIPC/ethylene treatments reduced sprout length compared with an untreated control in all varieties. CIPC alone controlled sprouting to less than 2 mm in all varieties for 2 months but was less effective thereafter in controlling sprouting in any variety other than Cabaret. However, combined treatment CIPC/ethylene controlled sprouting to commercially acceptable levels, a mean of approximately 2 mm or less, in all varieties except Hermes and Saturna, which had mean sprout lengths of 3.1 and 4.2 mm respectively after 6 months' storage. In all cases, sprout length was reduced in the combined treatment compared with either treatment alone. The mean sprout length for all varieties and sampling occasions with CIPC/ethylene treatment was significantly different from the mean for CIPC alone (P-values range from <0.001 to 0.004. Annex: Table 2). Good sprout control with CIPC/ethylene was observed in varieties, including Maris Piper, that were poorly controlled by ethylene treatment alone.

Generally, the highest French fry colour values in Cabaret, Maris Piper and Russet Burbank were found with CIPC/ethylene treatment, although they were all within commercially acceptable limits except for Cabaret after six months' storage. There were no consistent significant differences in chip fry colour for these varieties after 2, 4 and 6 months' storage between the CIPC/ethylene or CIPC treatments (Annex: Figure 1).

Ethylene reduced Hunter L values of crisps even in the presence of CIPC. The severity of effect was varietal. For example, the effect of ethylene on Saturna was smaller than with Hermes (Annex: Figure 2). Crisp colour tended to increase with storage duration with both treatments.

R464 (2014-15)

In this project, R464, during 2014-15 the treatments were 10 ppm ethylene, a single intake 9 g/tonne CIPC application and ethylene with 9 g/tonne CIPC. The following varieties were used: Arsenal, Chicago, Fontane, Lady Claire, Maris Piper, Markies, Ramos, Royal, Russet Burbank, VR808.

For all varieties at all sampling occasions, mean sprout length was smaller with the combination treatment than either treatment alone. Sprout length was commercially acceptable for all varieties, including those varieties in which ethylene alone provided poor control, and at all sampling occasions except for Lady Claire, 2 and 4 months only, and Royal, 2 months only (Annex: Table 3).

Ethylene had a statistically significant effect on French fry colour only for Fontane, after 2 and 4 months in store, and Ramos on all three sampling occasions. Despite this, French fry colours were commercially acceptable for all varieties and sampling occasions except for Royal after 2 months only. There were no statistically significant differences in fry colour between the treatments for Maris Piper, Markies or Russet Burbank when stored in either box or bulk store types. The results for box storage are shown in Annex: Tables 4 & 5.

Although ethylene treatment caused a slight decrease in crisp Hunter L score with Chicago, Lady Claire and VR808, the fry colours would have been commercially acceptable throughout the experiment (Annex: Table 6). However, defects were slightly increased following ethylene treatment (Annex: Table 7).

R464 (2015-16)

For all varieties and for every sampling occasion in 2015/16, except Ramos after 6 months' storage, the lowest mean sprout length was observed with CIPC 16g/t + ethylene with statistically significant differences from the other treatments in all varieties except for Maris Piper and Ramos. The lower dose CIPC 9g/t + ethylene treatment provided slightly less sprout control than the higher dose CIPC 16g/t + ethylene.

Overall, treatment with ethylene resulted in slightly darker average fry colour scores, although only for Markies after 8 months' storage were statistically significant differences found between treatments with and without ethylene. Previous trials, which did not show a marked effect of ethylene on fry colour on Markies, were stored for 6 months.

The trials support the findings of Daniels-Lake *et al* (2011), who studied the potential for reduced use of CIPC by combination treatment of CIPC (Sprout-Nip E, 1000 ppm dip) with ethylene (4 ppm). They reported on the sprout inhibition in two varieties by combination treatment; on the negative effect on processing colour in both cultivars when ethylene was included in the treatment and also on varietal response differences to treatment.

CIPC treatment dose

The trials demonstrated a synergistic effect of CIPC with ethylene with respect to control of sprouting. The ethylene treatment was fixed at a concentration of 10ppm throughout. The dose of CIPC varied depending on the then maximum single application dose, or to trial for very low CIPC dose (9 ppm). All doses were effective with the higher doses providing the better results. A single dose of CIPC applied at intake in combination with ethylene was sufficient for sprout control for at least six months for all varieties except Lady Claire (9 ppm CIPC only).

An effect of ethylene on fry colour was observed for most varieties in all years of the trials; the size of this effect varied with variety. Generally, however, the effect was small and did not affect commercial acceptability.

For some varieties, ethylene did provide significantly different results from CIPC alone. However, there was variation in these results across years. For example, fry colour in Markies in 2014-15 was significantly darker that CIPC treatment alone whereas in the three previous years there were no significant differences between the treatments. Fry colours for Maris Piper and Russet Burbank were always unaffected by ethylene.

2.5 Conclusions

Based on these trials, a combination CIPC/ethylene treatment can provide a practically useful sprout control strategy for long term storage of some processing varieties.

It is notable that combination treatment provided better sprout control than either treatment alone. Combined treatment also removed the varietal variability component of sprout control by ethylene alone.

The effect of ethylene on processing fry colour exhibited a varietal component but generally had little or no influence on commercial acceptability. However, individual varieties would require to be tested for ethylene response with regard to fry colour prior to the use of a combination CIPC/ethylene sprout suppression treatment.

3. References

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4. Summary of knowledge transfer

Potato Processors' Association joint working party, SBCSR, 15 Nov 2016.

Update to AHDB Potatoes R&KT committee, SBCSR, 9 Nov 2016.

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