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The Performance of Carbon Filters at Different Smoking Regimes

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Introduction

- Previous work presented at 61st TSRC compared the adsorption characteristics of cigarette filters containing fixed weights and fixed volumes of activated carbons from different raw materials at different activity levels
- As expected, the retention of vapour phase compounds by a carbon filter increased as a function of increasing carbon weight, bed length and activity.
- In general, coconut and coal-based carbons behaved similarly
- The vapour phase retention of many of the filters studied was very high. However, all testing was carried out under ISO smoking regimes and it is not known to what extent these efficiencies may change under more intense regimes.

Experimental Plan

- This work compares the retention of carbon filters under three different smoking regimes – ISO, Massachusetts and Canadian Intense
- For the purposes of simplicity, the current study was limited to non-ventilated cigarettes so vent-blocking effects would not be a factor
- Although fixed weight and fixed volume protocols both provide valid means of comparing carbon filters, weight-based methods were used as they are easier to control in the laboratory
- In addition to smoking regime, this work explores the effects of:
  - ➢ Carbon raw material – coconut and coal
  - ➢ Carbon activity level – ‘low’, ’medium’ and ‘high’
  - ➢ Carbon weight – 60mg and 100mg per tip

Materials Tested

Coconut-based carbons

- Two commercially available carbons - ‘medium’ and ‘high’ activities
- Referred to in this paper as ‘CTM’ and ‘CTH’.

Coal-based carbons

- Three commercially available carbons - ‘low’, ‘medium’ and ‘high’ activities
- Referred to in this paper as ‘CLL’, ‘CLM’ and ‘CLH’

- All samples were selected to the same particle size range (30/70 US mesh)

Carbons Tested - Physical Analysis

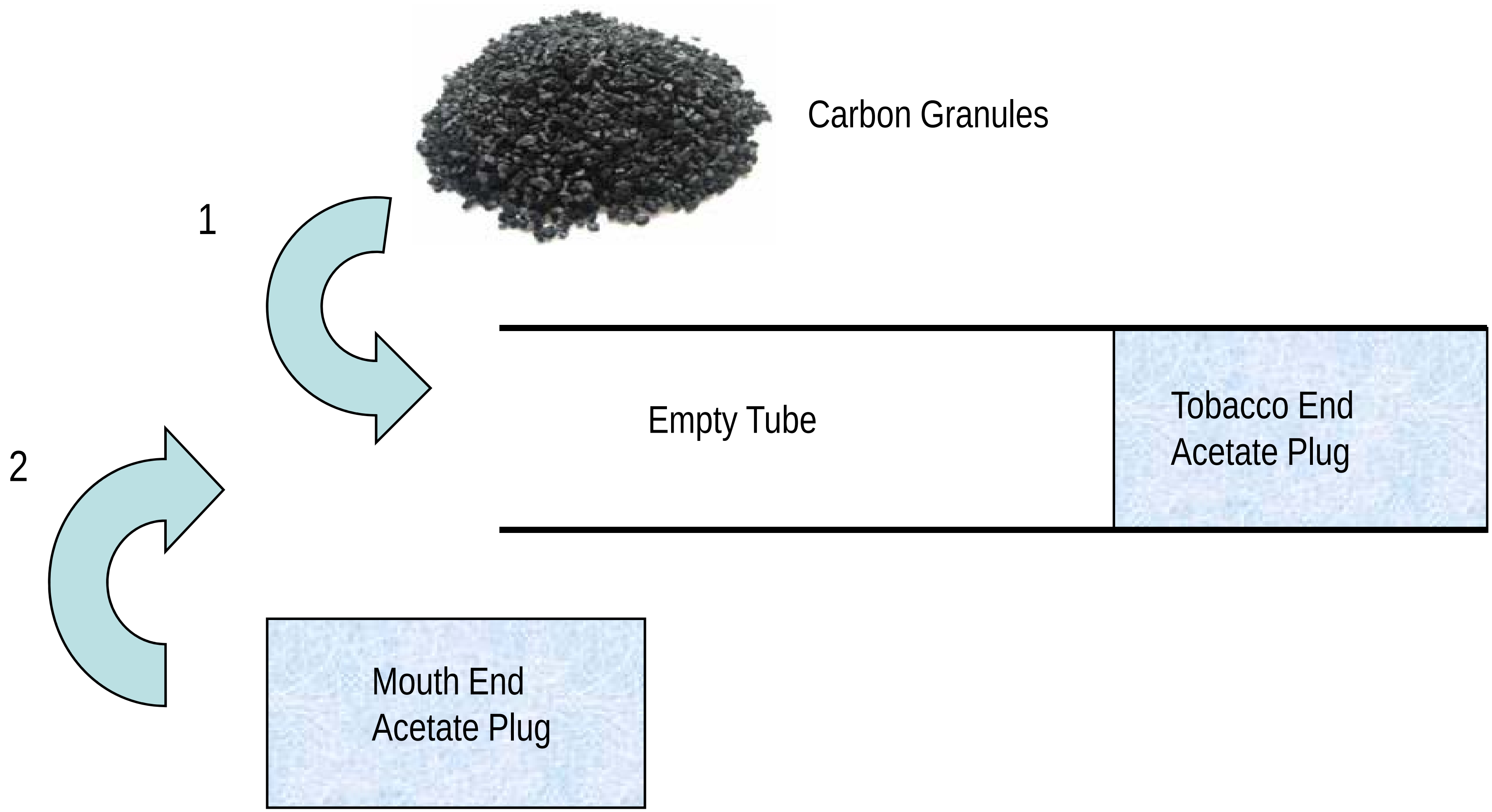
Raw Material	Sample Ref	Moisture Content (%)	Wet Density (g/ml)	Cyclohexane Activity (%)	BET Surface Area (m^2/g)
Coconut	CTM	17.4	0.60	27.2	1150
	CTH	9.3	0.45	45.5	1600
Coal	CLL	6.9	0.82	12.7	650
	CLM	11.7	0.54	28.8	1000
	CLH	4.3	0.41	49.6	1350

Note: Surface area – manufacturers' data

Filter Designs and Assembly

- Hand-assembled triple granular filters, ensuring that 100% granular fill of the cavity was obtained
- Two fixed weights - 60 mg and 100 mg carbon
- Carbons dried prior to filter assembly
- Same filter, but with with empty cavity, used on the control cigarette

Test Filter


Carbon Granules
1
2
Empty Tube
Tobacco End
Acetate Plug
Mouth End
Acetate Plug

Analytical Procedures

Methodology

- Cigarettes tested around three weeks after assembly
- Vapour phase collected in gas sampling bag for analysis by GC-MS
- Tar, nicotine and CO Yields also measured at all three smoking regimes

Vapour Phase Compounds Measured

- Aldehydes – Acetaldehyde, Acrolein, Propionaldehyde, Butyraldehyde and Crotonaldehyde
- Ketones - Acetone and Methyl Ethyl Ketone
- Hydrocarbons – 1,3 Butadiene, Isoprene, Benzene and Toluene
- Cyanides – Acrylonitrile

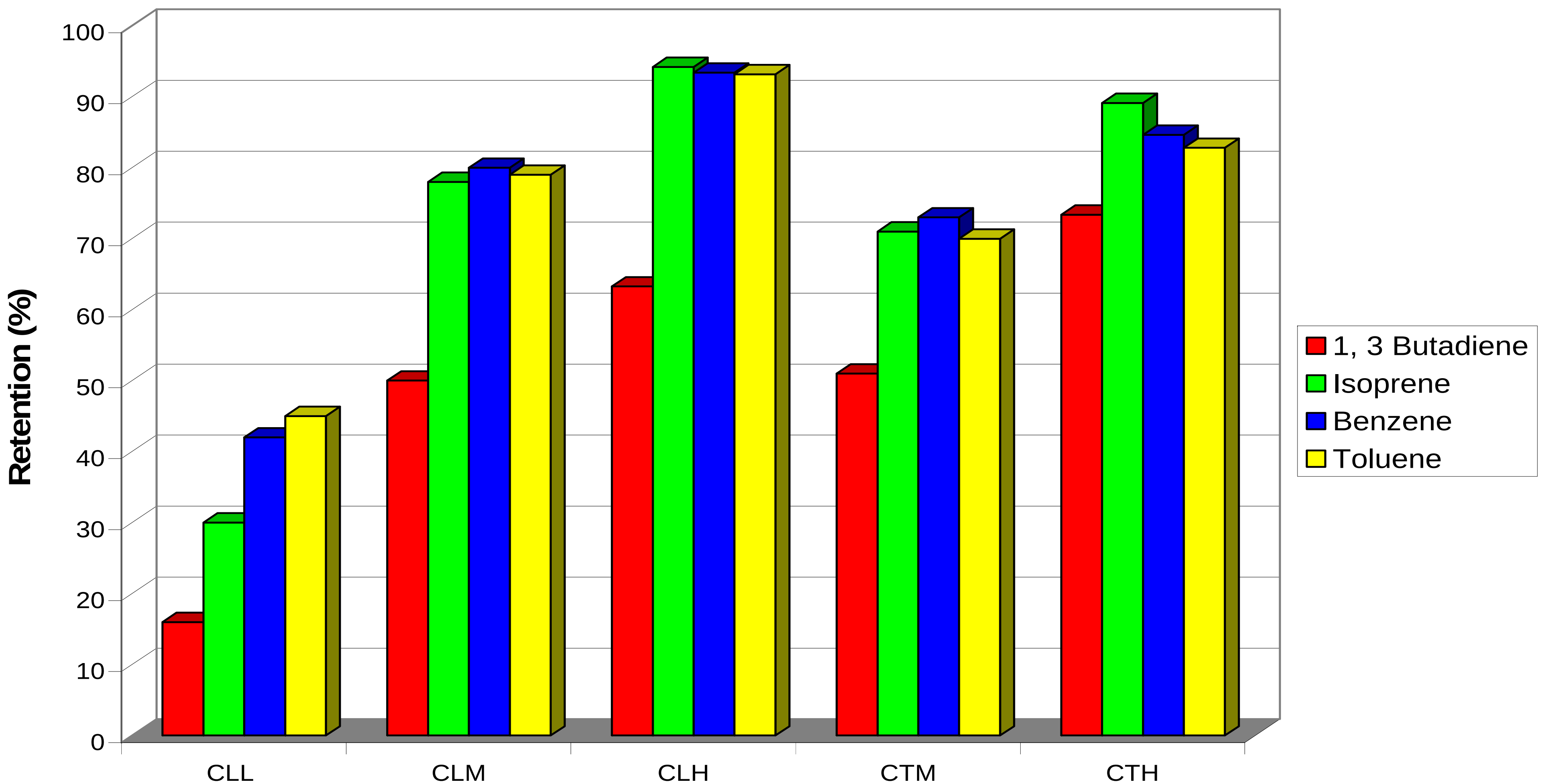
Calculation of Compound Vapour Phase Retention

$$\% \text{ Retention} = \frac{(\text{Control Cigarette GC Peak Area} - \text{Test Cigarette GC Peak Area}) \times 100}{\text{Control Cigarette GC Peak Area}}$$

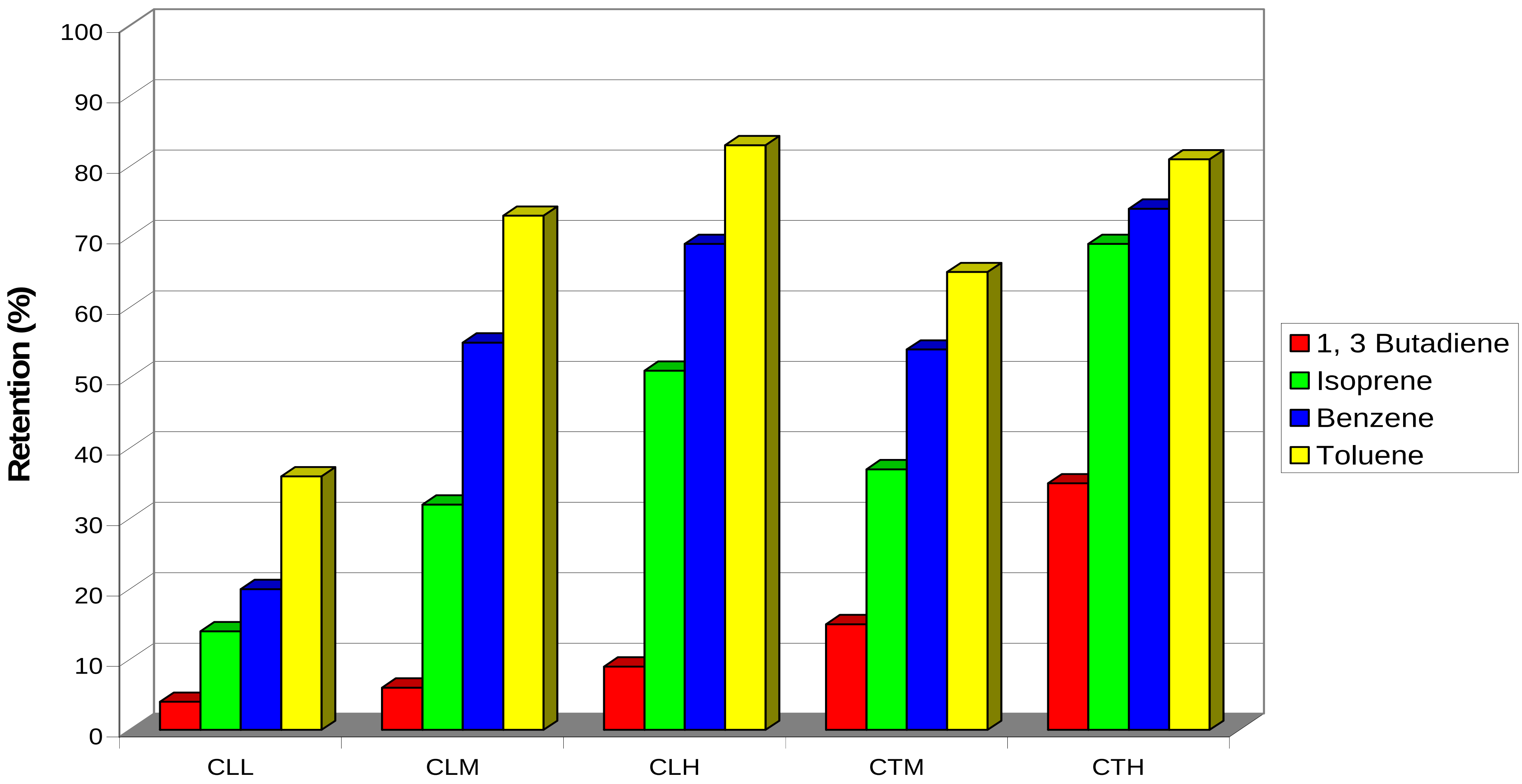
Smoke Testing

Smoking Regime	Puff Regime	Puff Number	Tar Delivery (mg/cig)	Nicotine Delivery (mg/cig)	CO Delivery (mg/cig)
ISO	35/2/60	7.8	13.3	0.97	13.2
Mass	45/2/30	11.9	23.6	1.74	20.5
Canadian	55/2/30	10.8	26.3	1.83	22.9

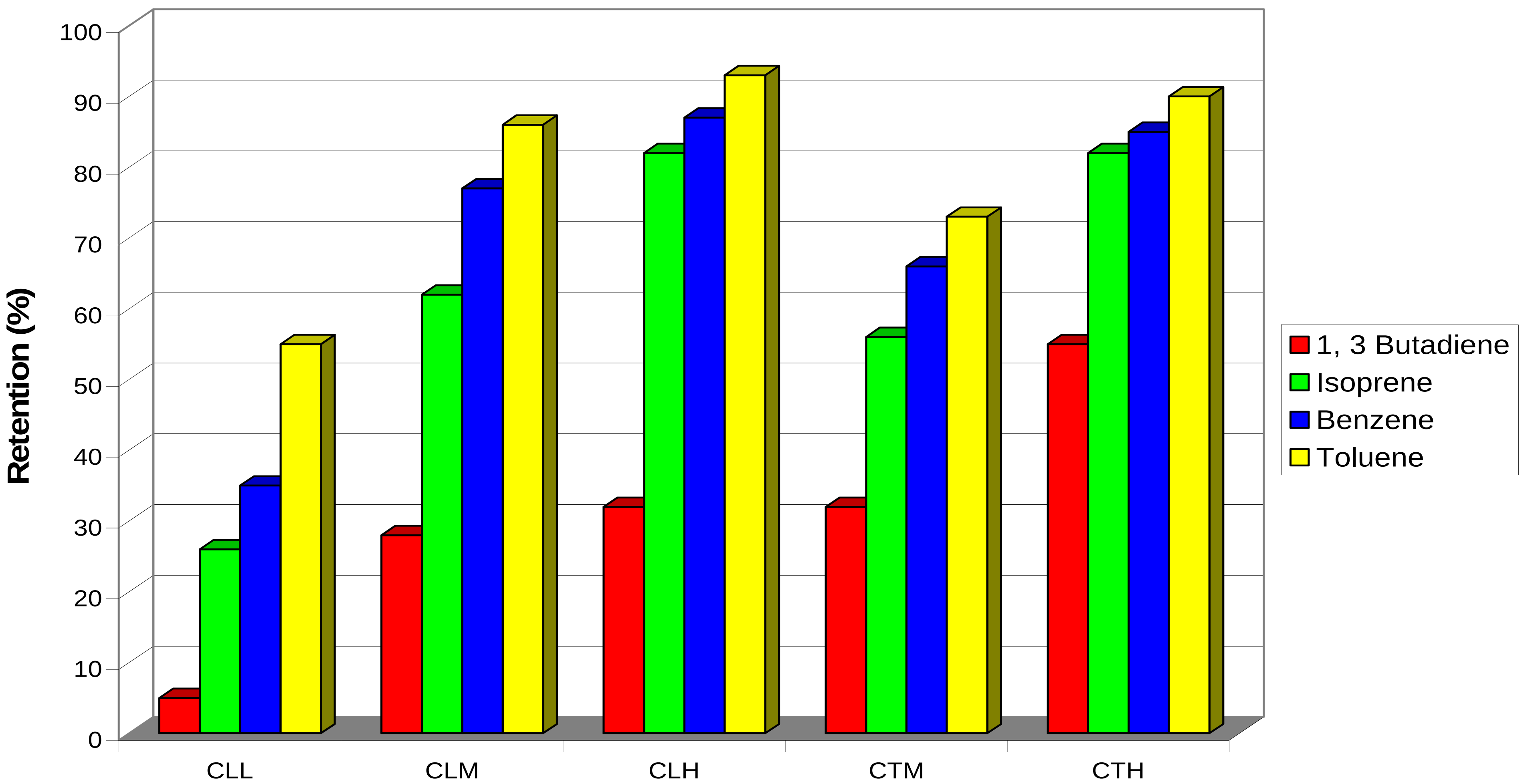
Retention of Hydrocarbons – ISO Smoking (60mg/tip)



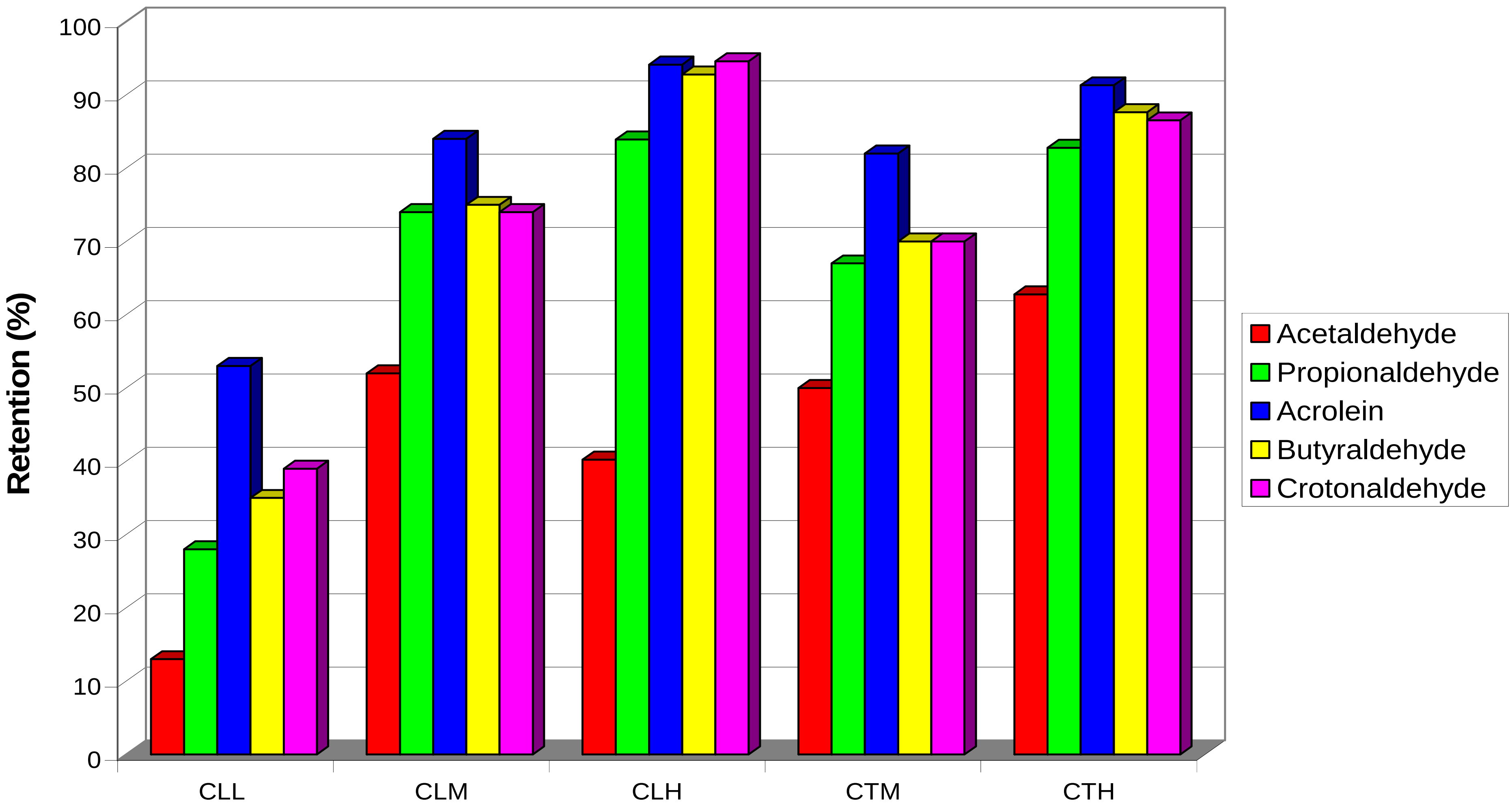
Retention of Hydrocarbons – Canadian Intense Smoking (60mg/tip)



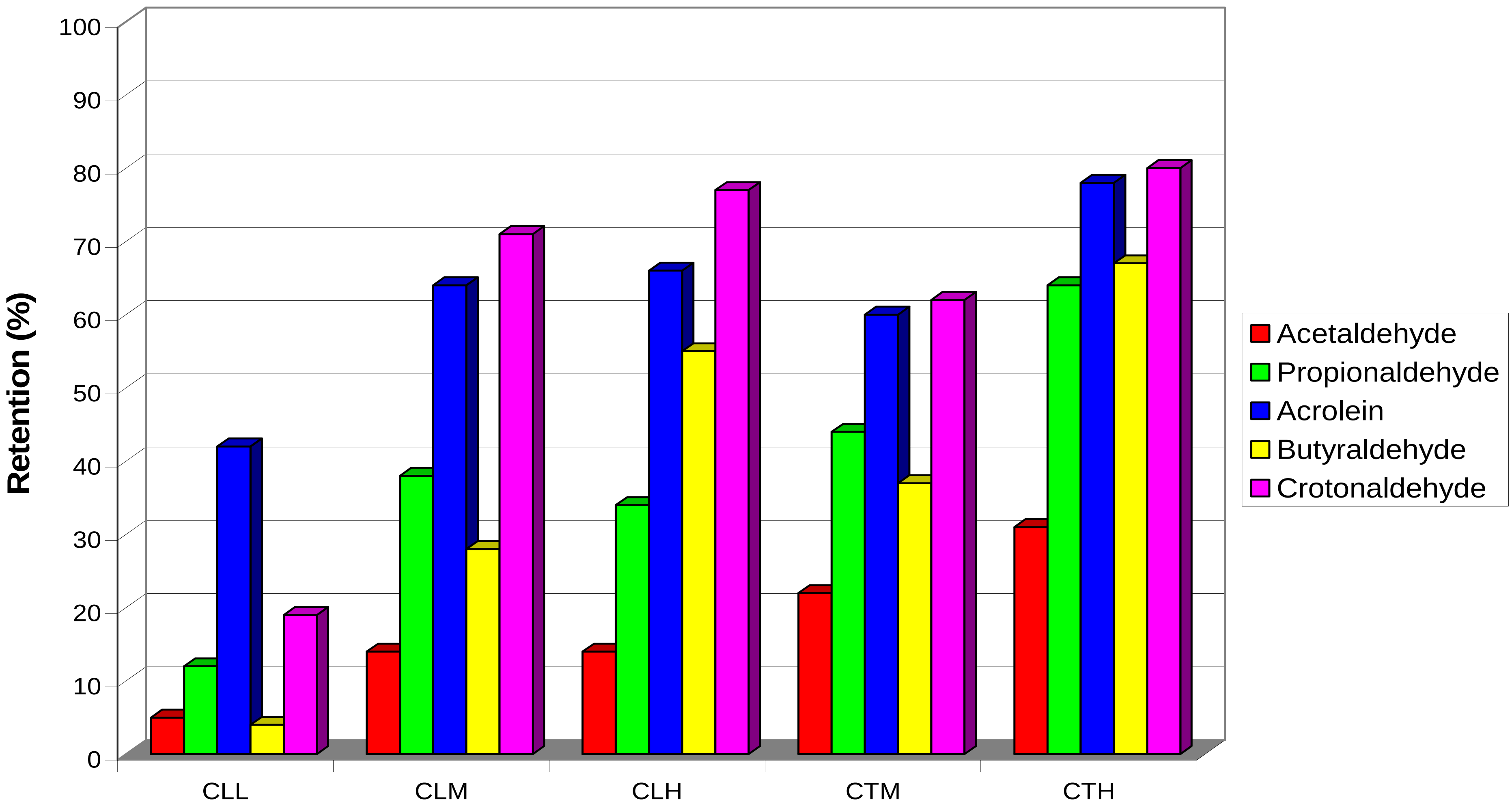
Retention of Hydrocarbons – Canadian Intense Smoking (100mg/tip)



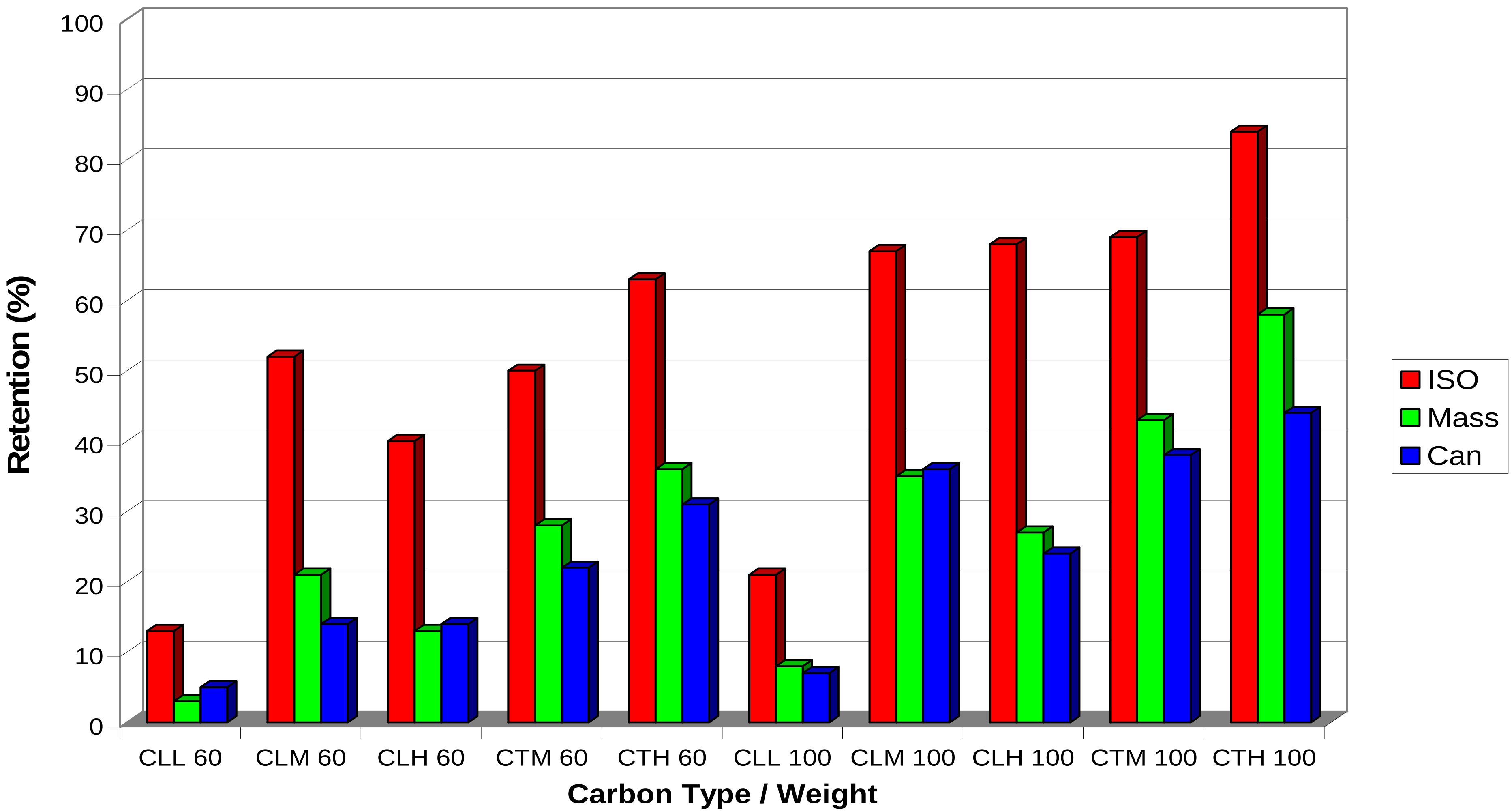
Retention of Aldehydes – ISO Smoking (60mg/tip)



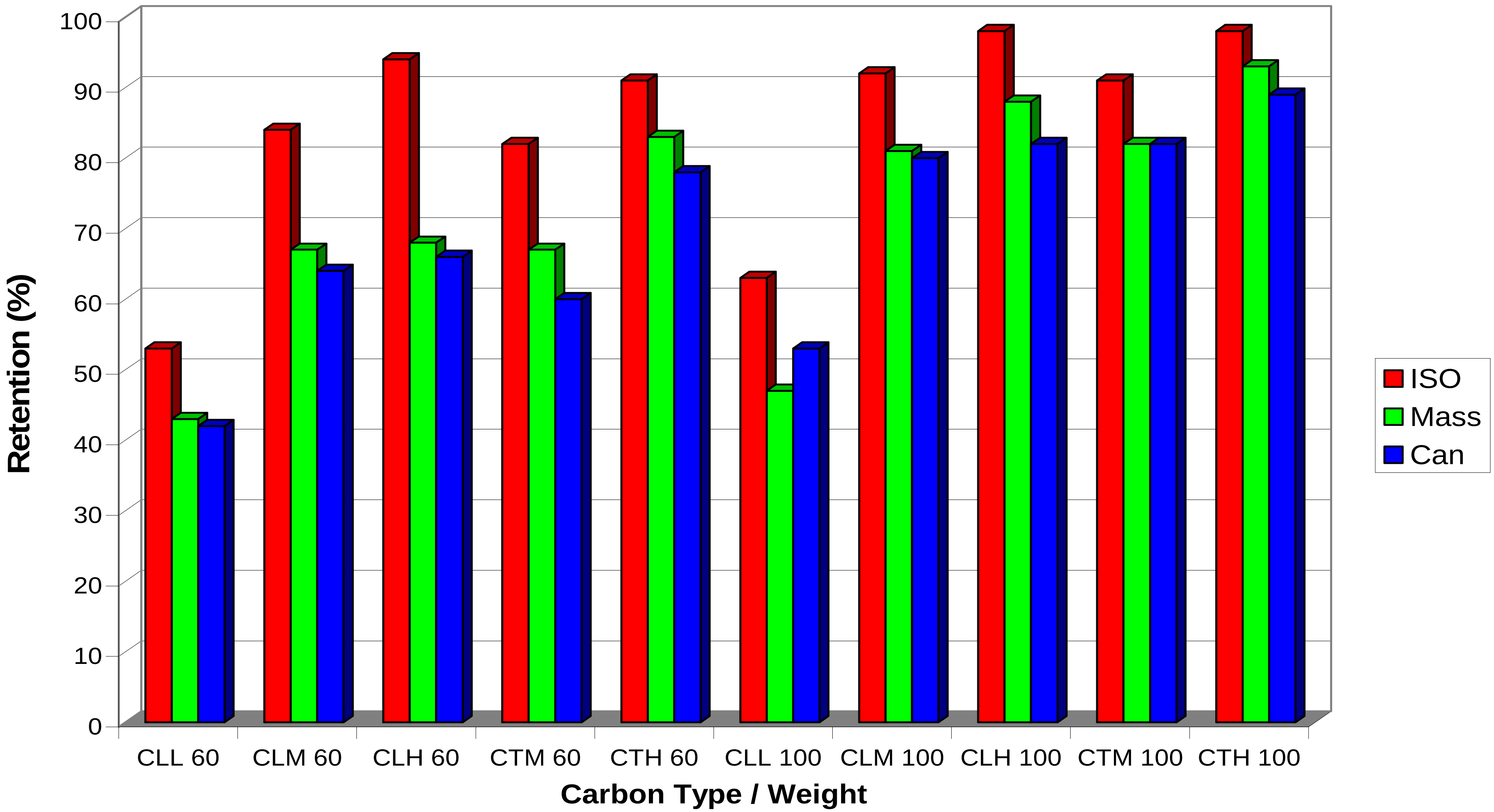
Retention of Aldehydes – Canadian Intense Smoking (60mg/tip)



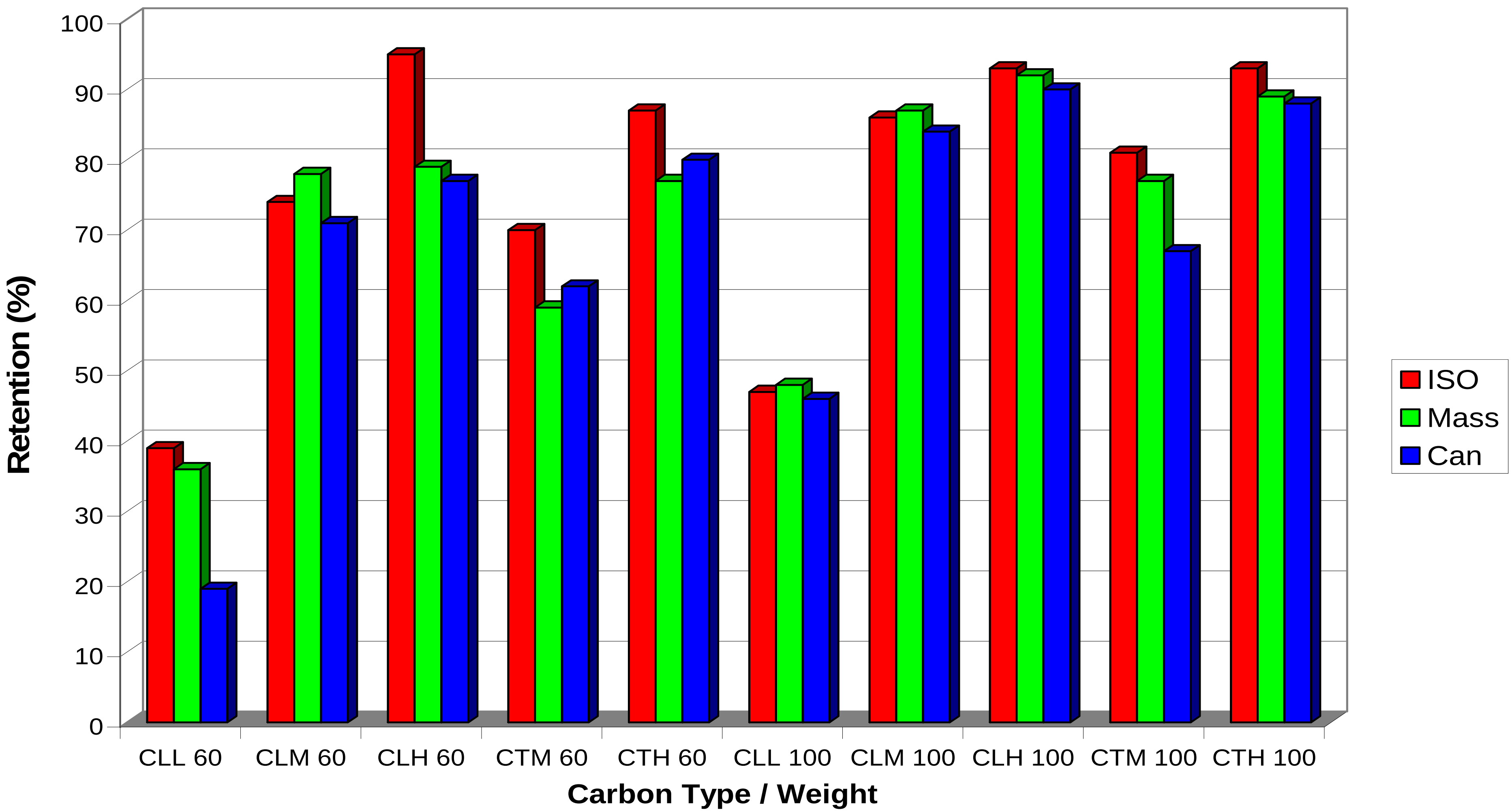
Effect of Smoking Regime on Acetaldehyde Retention



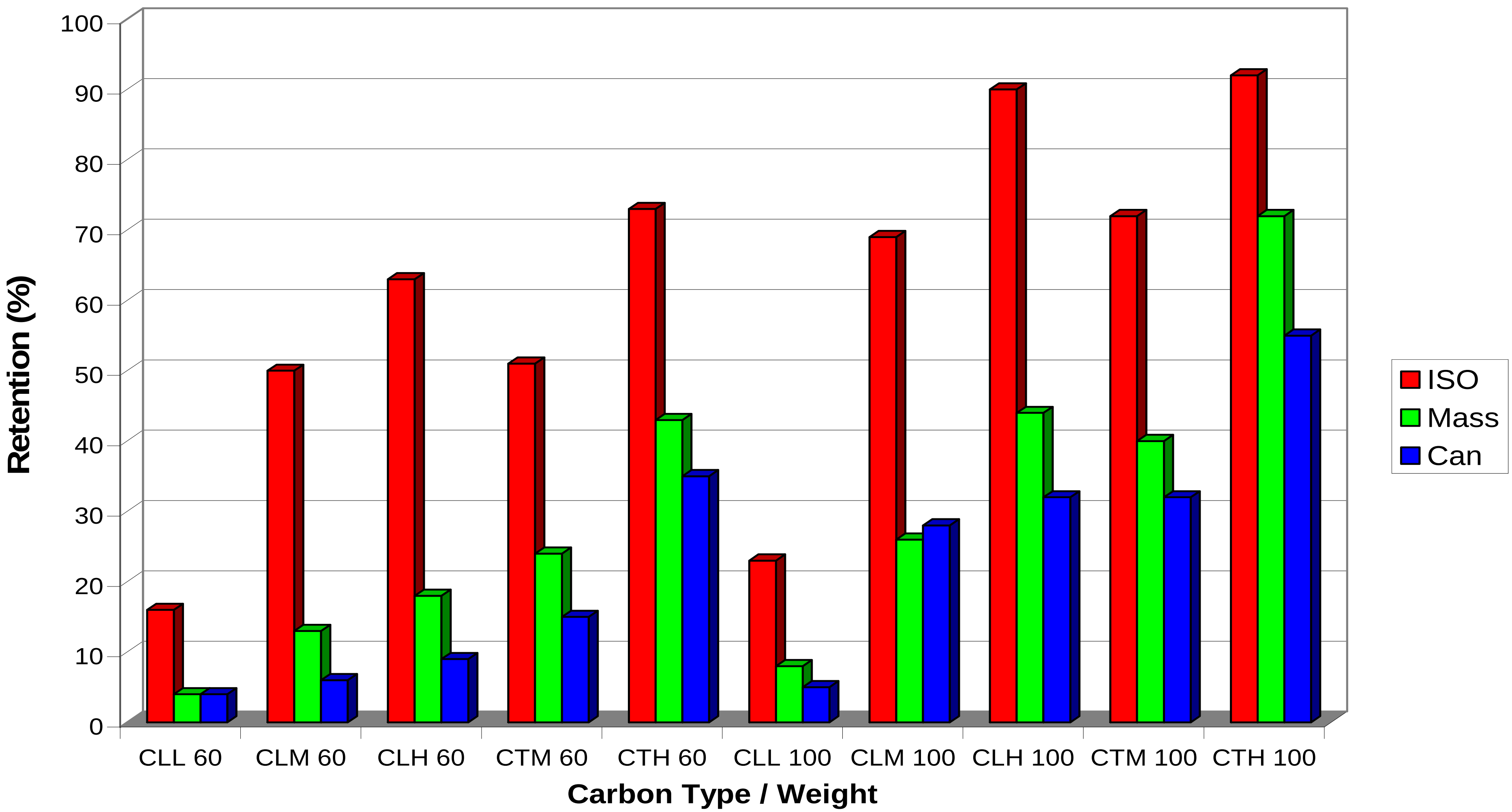
Effect of Smoking Regime on Acrolein Retention



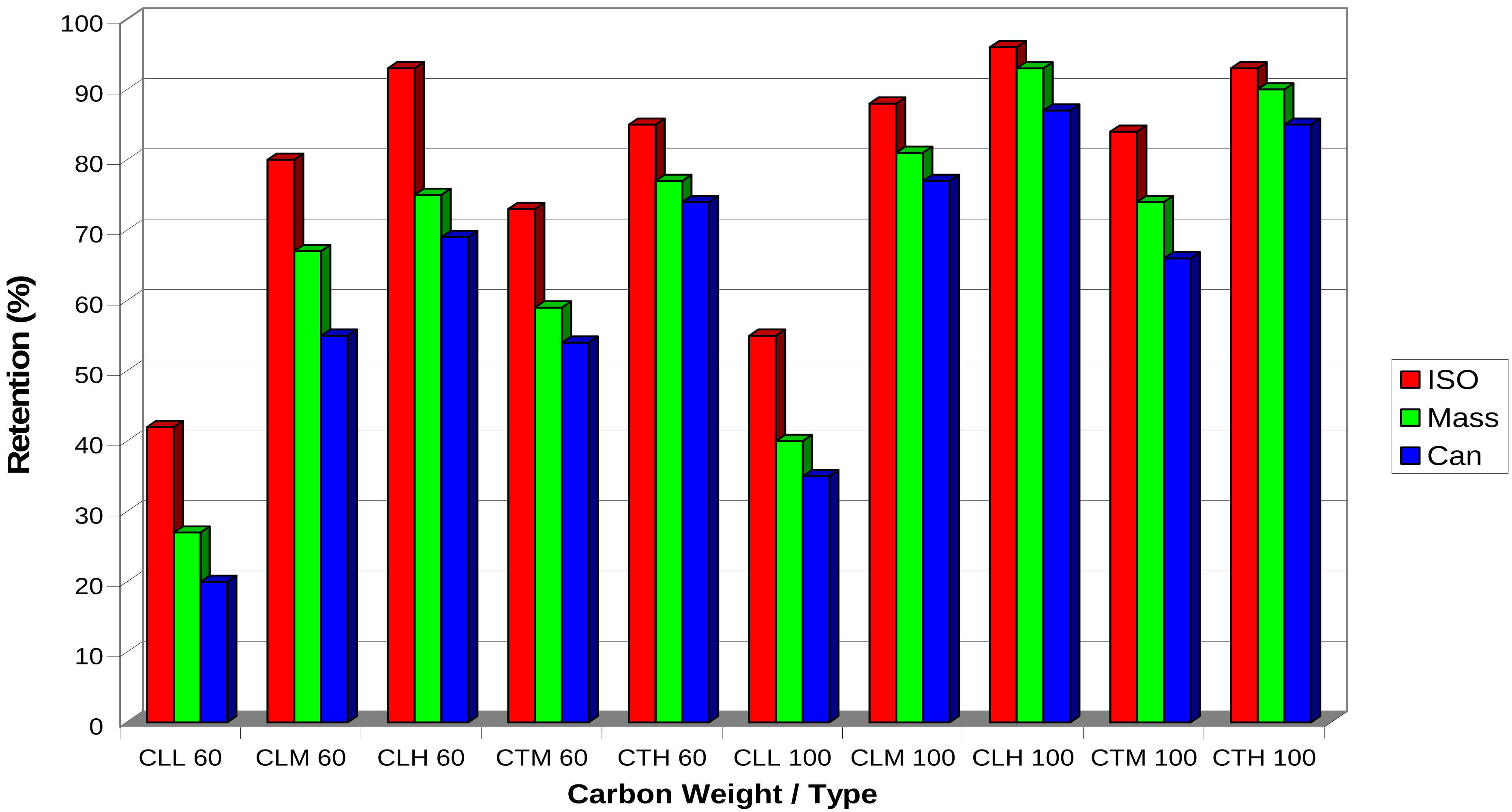
Effect of Smoking Regime on Crotonaldehyde Retention



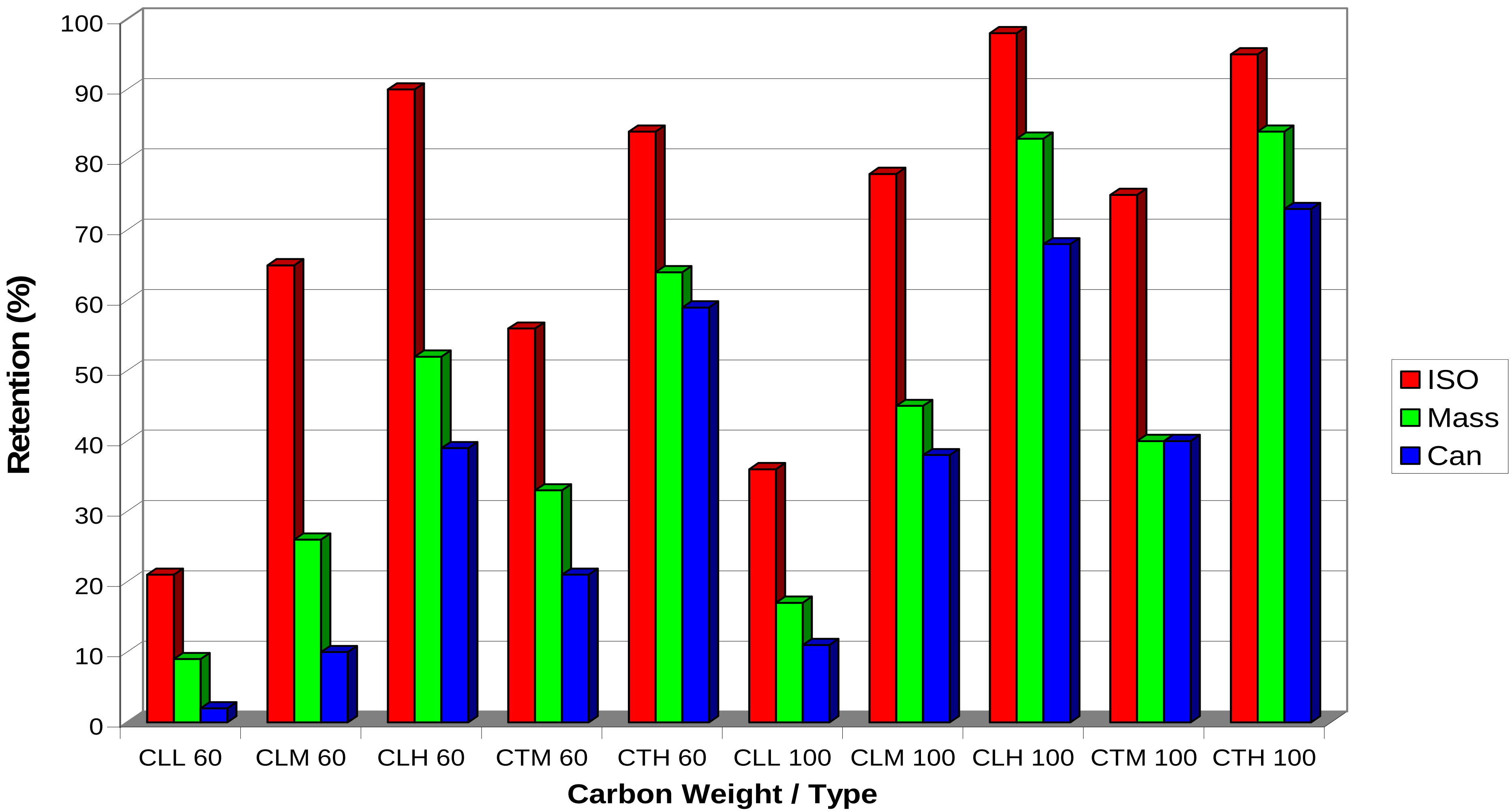
Effect of Smoking Regime on 1,3-Butadiene Retention



Effect of Smoking Regime on Benzene Retention



Effect of Smoking Regime on Acrylonitrile Retention



Conclusions

- The retention of vapour phase compounds by a carbon filter decreases as the intensity of the smoking regime increases, with the magnitude of the effect being a function of compound volatility within each chemical grouping.
  - Lower boiling vapour phase compounds tend to be less well retained by carbon filters under more intense smoking regimes, particularly at lower carbon weights.
  - Conversely, more intense smoking regimes have a relatively small effect on the retention of the higher boiling vapour phase point compounds, particularly at higher carbon weights
- The increase in vapour phase retention by a carbon filter as a function of increasing carbon weight and increasing carbon activity that was previously observed under ISO conditions can also be seen under Massachusetts and Canadian regimes
- Coconut and coal-based carbons of similar activity gave broadly similar removal efficiency, with the exception of the more volatile compounds (e.g. acetaldehyde and 1,3-butadiene) for which coconut carbons gave greater retention. These differences are even more apparent under more intense regimes.
- The relative loss in retention under more intense smoking regimes is more noticeable for lower activity carbons.

Further Studies

- This study has only considered retention rather than yield data.
- Although vapour phase retention is reduced under more intense regimes, it must be remembered that a greater quantity of material is passing through the filter and hence the actual amount of material adsorbed by the carbon may be greater.
- A further paper will be presented at CORESTA 2008 examining vapour phase yields using coconut carbons in the weight range 15 – 150 mg/tip at different smoking regimes.

Thank you for your attention