

Storage study of US Citra and GER Perle: a real-world examination of Hop Storage Index, Alpha Degradation, Total Oil and Hop Aroma Compounds

- One piece of total hop quality is from packaging of hop pellets to use in the brewing process. In this study, the ageing of pellet hops, both at cold and room temperatures, was investigated over a four year period with the hops Citra (USA) and Perle (Germany) in foils packaged with inert gas. During ageing, Hop Storage Index (HSI), HPLC bitterness compounds (EBC 7.7) and GC-FID of hop aroma compounds were analyzed at periodic intervals. This study is unique because of its real-world time period of four years over which the hops were studied. Hops stored cold provided excellent alpha-acid and HSI stability, whereas at room temperature, a continual loss of alpha acids and increase of HSI was observed. Hop oil showed similar losses both at cold and room temperature after the first few months of storage. Once these initial hop oil losses occurred, hop oil stabilized. Selected hop aroma compounds will also be shown in this work. The brewer can utilize these results as a guide to be able to make decisions when dosing hops with similar ageing characteristics after prolonged storage.



Storage study of US Citra and German Perle: a real-world examination of bittering compounds, Hop Storage Index, total oil and hop aroma compounds

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“Freshness is a measure of the degree to which the hop compounds remain unchanged from the time of harvest until they enter the wort in the brewing process.”

Hops: Their Cultivation, Composition and Usage – Biendel, et. al.



Growing/harvesting conditions



Storage and processing from whole cone bales to hop pellets



Storage until addition into brewing process



Study

- Real-world storage study of the most valuable ingredients in normal pellet hops (T90s)
- Temperatures: cold at 3°C (37.4°F) and ambient at 25°C (77°F)
- Storage time of 38 months



US Citra®
2022: 20,616 acres

2018 harvest



German Perle
16,927 acres

Methods

- Bittering compounds:

- ASBC Hops 6A/12

- Alpha and beta acids/Hop Storage Index (HSI) in hops and pellets
- Spectrophotometry ultraviolet (UV)

- EBC 7.5

- Bitter substances in hops and hop products
- Lead conductance value (LCV)

- EBC 7.7

- Alpha and beta-acids in hops and hop products
- High-performance liquid chromatography (HPLC)

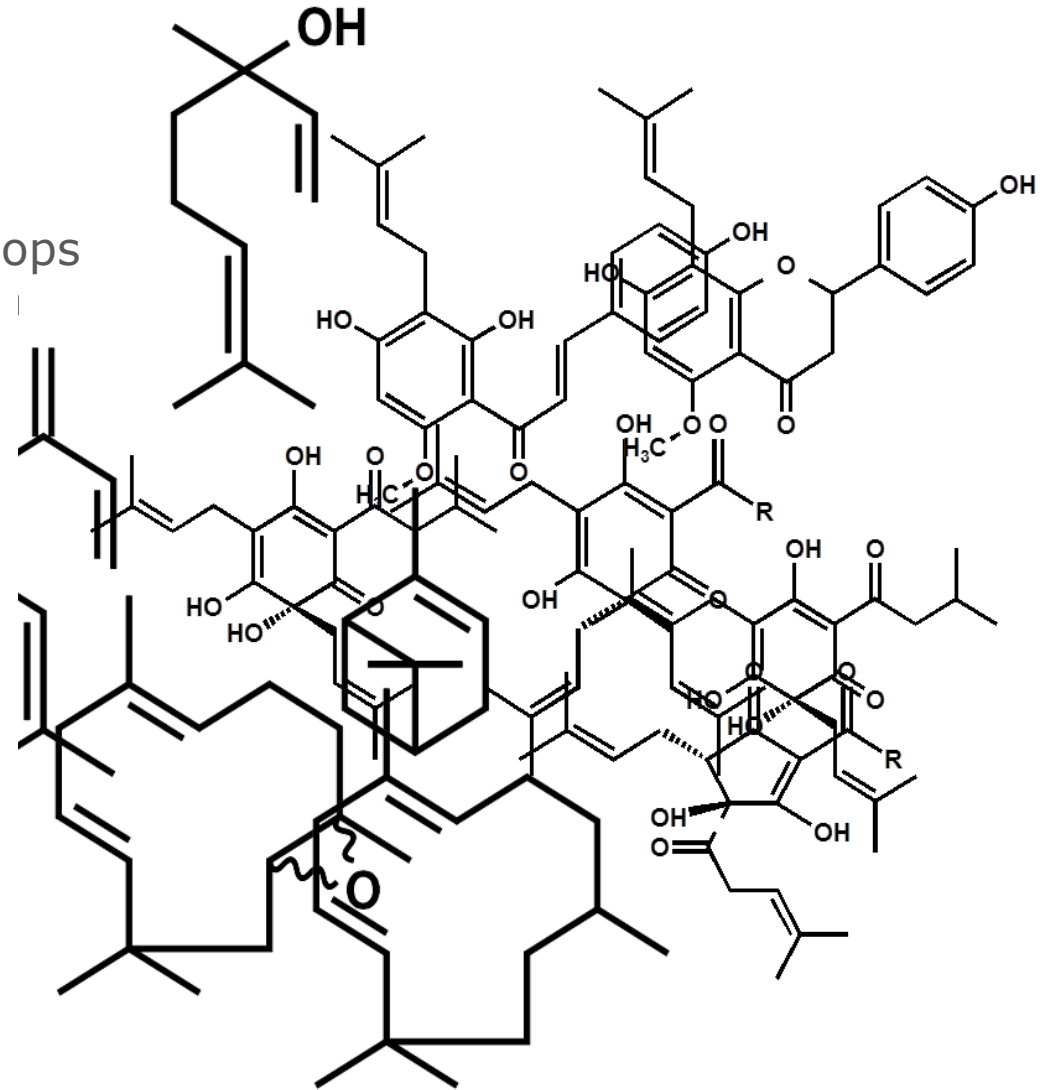
- Oil compounds:

- EBC 7.10

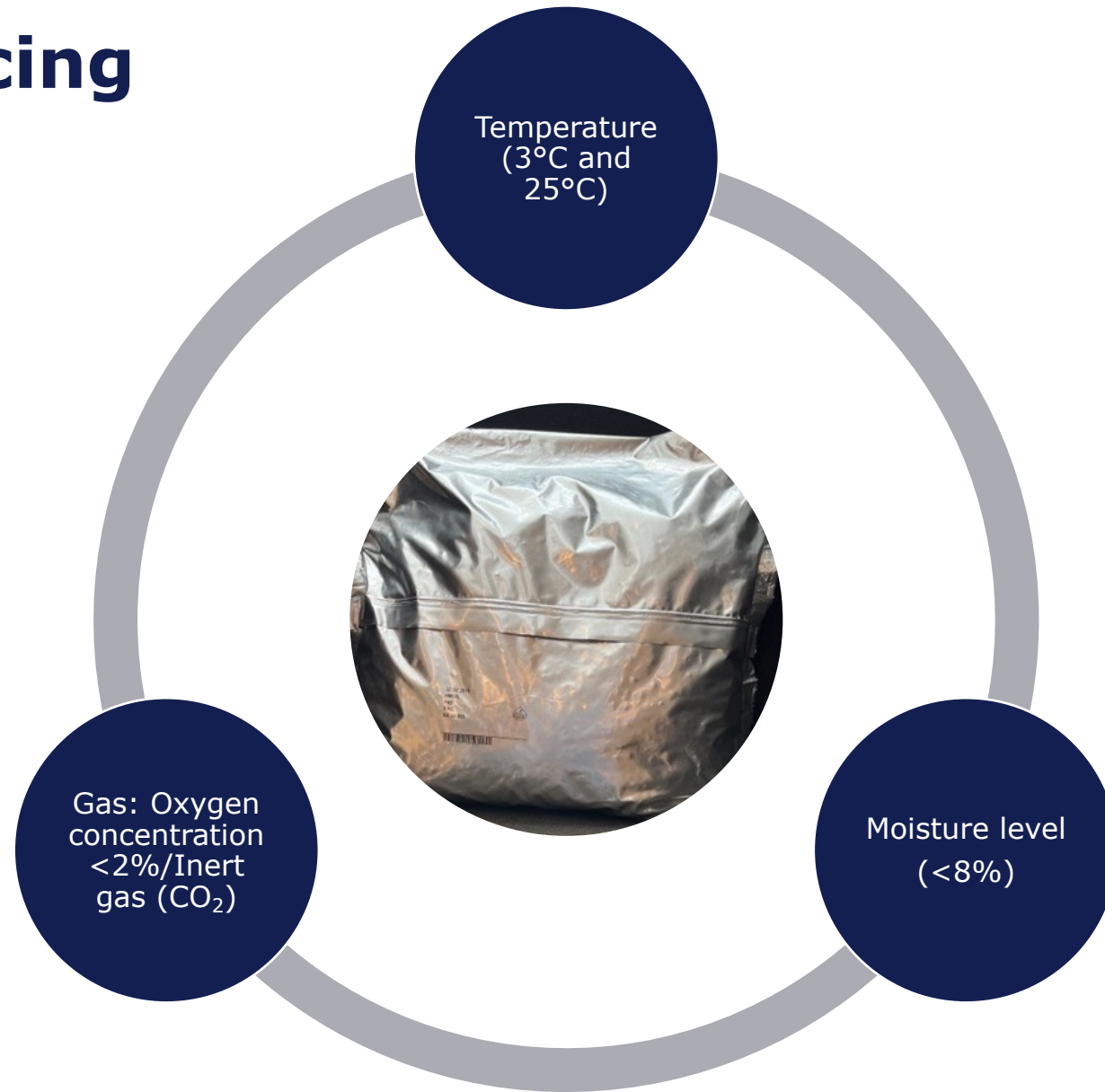
- Hop oil content of hops and hop products
- Steam distillation

- EBC 7.12

- Hop essential oils by capillary gas chromatography flame ionization detection (GC-FID)



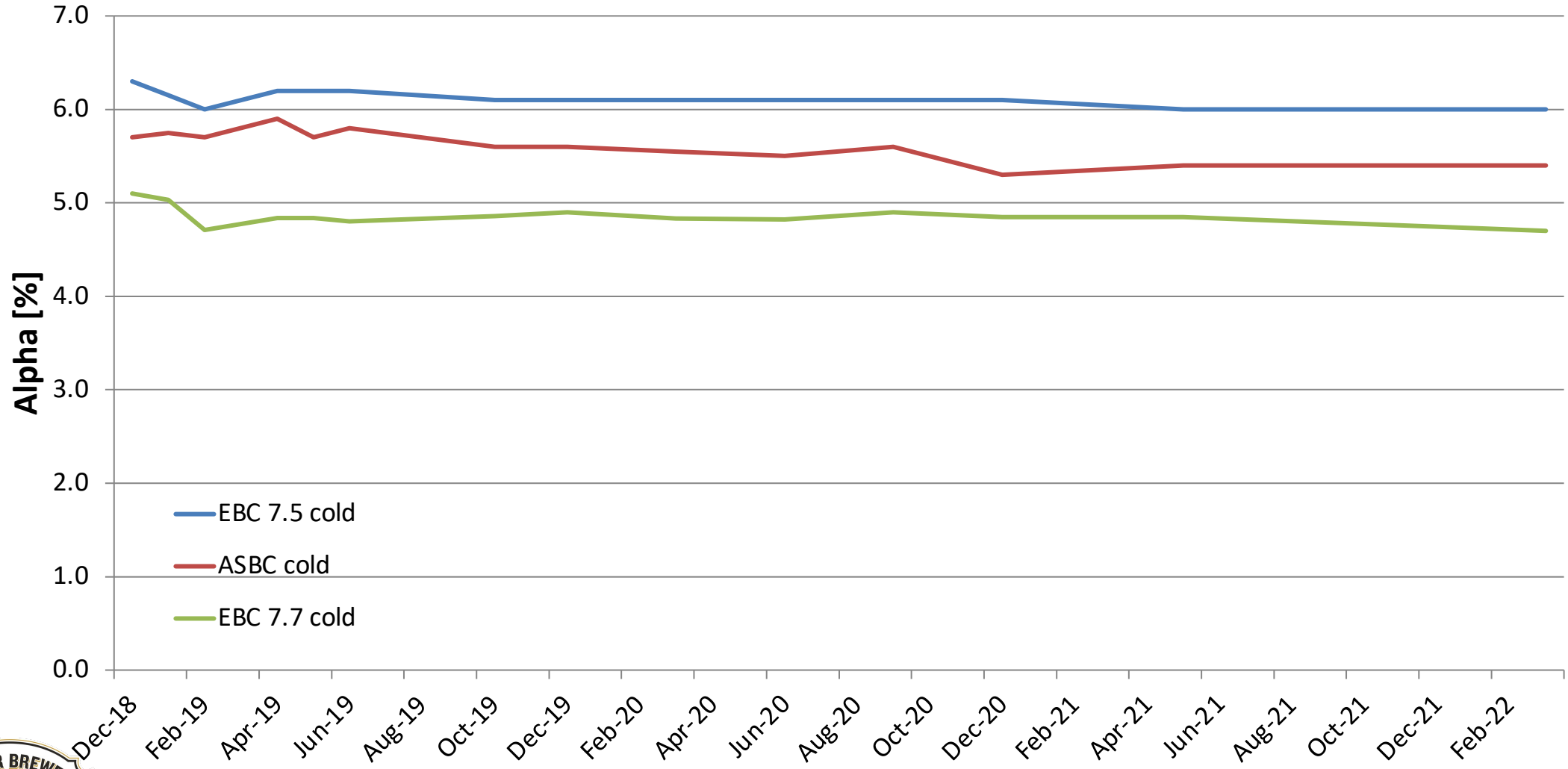
Factors Influencing Storage



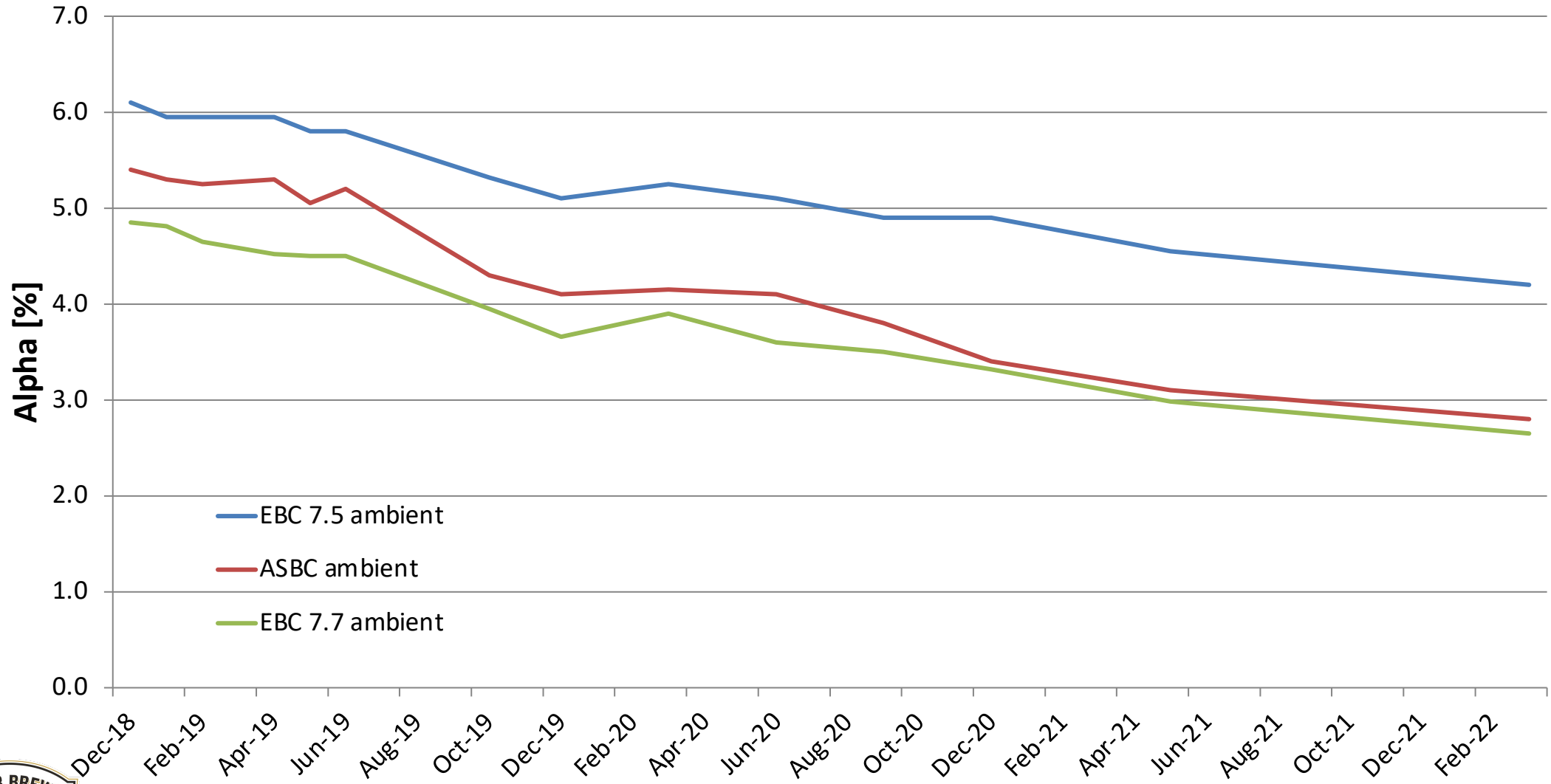


Perle Storage

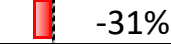
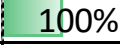

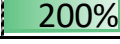

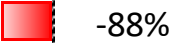
Perle Cold



Perle Ambient



Perle Aroma Components [mg/100 g]

	Cold		
	Dec 2018	March 2022	
Myrcene	274	189	 -31%
Limonene	1	2	 100%
Beta-Caryophyllene	141	133	 -6%
Farnesene	1	3	 200%
Alpha-Humulene	402	443	
2-Methylpropyl 2-methylpropanoate	3	1	
3-Methylbutylpropanoate	1	0	
3-Methylbutyl 2-methylpropanoate	1	0	
2-Methylbutyl 2-methylpropanoate	17	3	 -82%
Linalool	3	2	
Methyldecanoate	2	0	
2-Undecanone	5	4	
Methyl-deca-4-enoate	1	1	
Methylgeranate	2	1	
Citronellol	0	0	
Nerol	0	0	
Geraniol	1	1	
Caryophyllenoxide	3	1	
Humulenepoxid I	2	1	
Humulenepoxid II	8	1	 -88%
Humulenepoxid III	1	0	



Perle Aroma Components [mg/100 g]

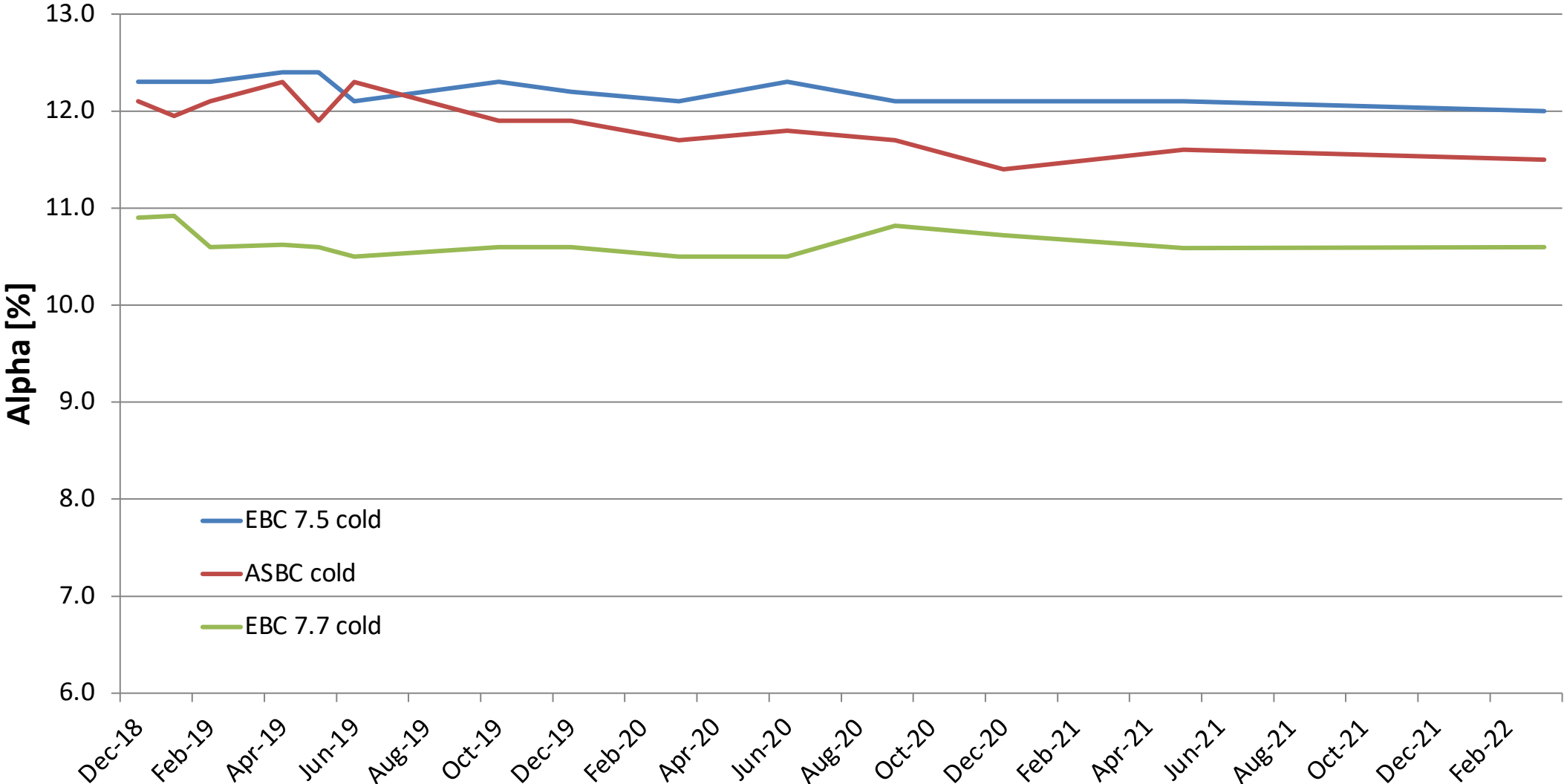
	Cold		
	Dec 2018	March 2022	
Sum of monoterpens	290	210	█ -28%
Sum of sesquiterpenes	604	651	█ 8%
Sum of hydrocarbon fraction	894	864	█ -3%
Sum of oxygenated fraction	80	45	█ -44%
Sum of all esters	33	27	█ -18%
Sum of monoterpene alcohols and esters	7	7	█ 0%
Sum of sesquiterpene alcohols	13	16	█ 23%
Sum of ketones	18	16	█ -11%
Sum of epoxides	14	3	█ -79%



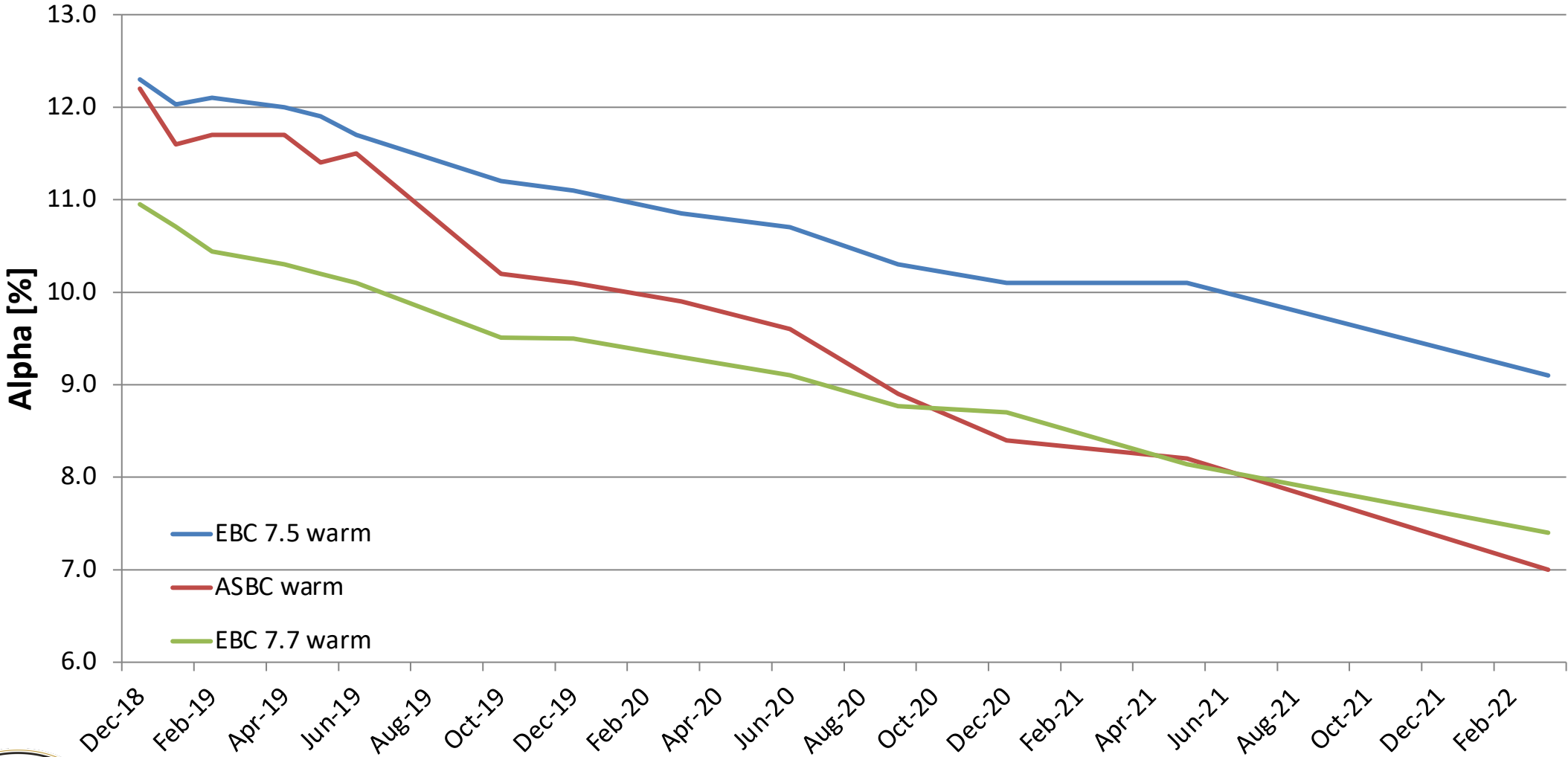


Citra Storage

Citra Cold



Citra Ambient



Citra Aroma Components [mg/100 g]

	Cold		
	Dec 2018	March 2022	
Myrcene	1236	1056	-15%
Limonene	3	9	200%
Beta-Caryophyllene	131	114	-13%
Farnesene	1	7	558%
Alpha-Humulene	224	220	
2-Methylpropyl 2-methylpropanoate	2	2	
3-Methylbutylpropanoate	5	3	-40%
3-Methylbutyl 2-methylpropanoate	10	9	-10%
2-Methylbutyl 2-methylpropanoate	39	36	-8%
Linalool	15	16	
Methyldecanoate	25	5	-81%
2-Undecanone	18	14	-22%
Methyl-deca-4-enoate	43	33	-23%
Methylgeranate	21	23	
Citronellol	0	0	
Nerol	0	1	
Geraniol	11	9	-18%
Caryophyllenoxide	1	1	
Humulenepoxid I	1	1	
Humulenepoxid II	3	1	-67%
Humulenepoxid III	0	0	



Citra Aroma Components [mg/100 g]

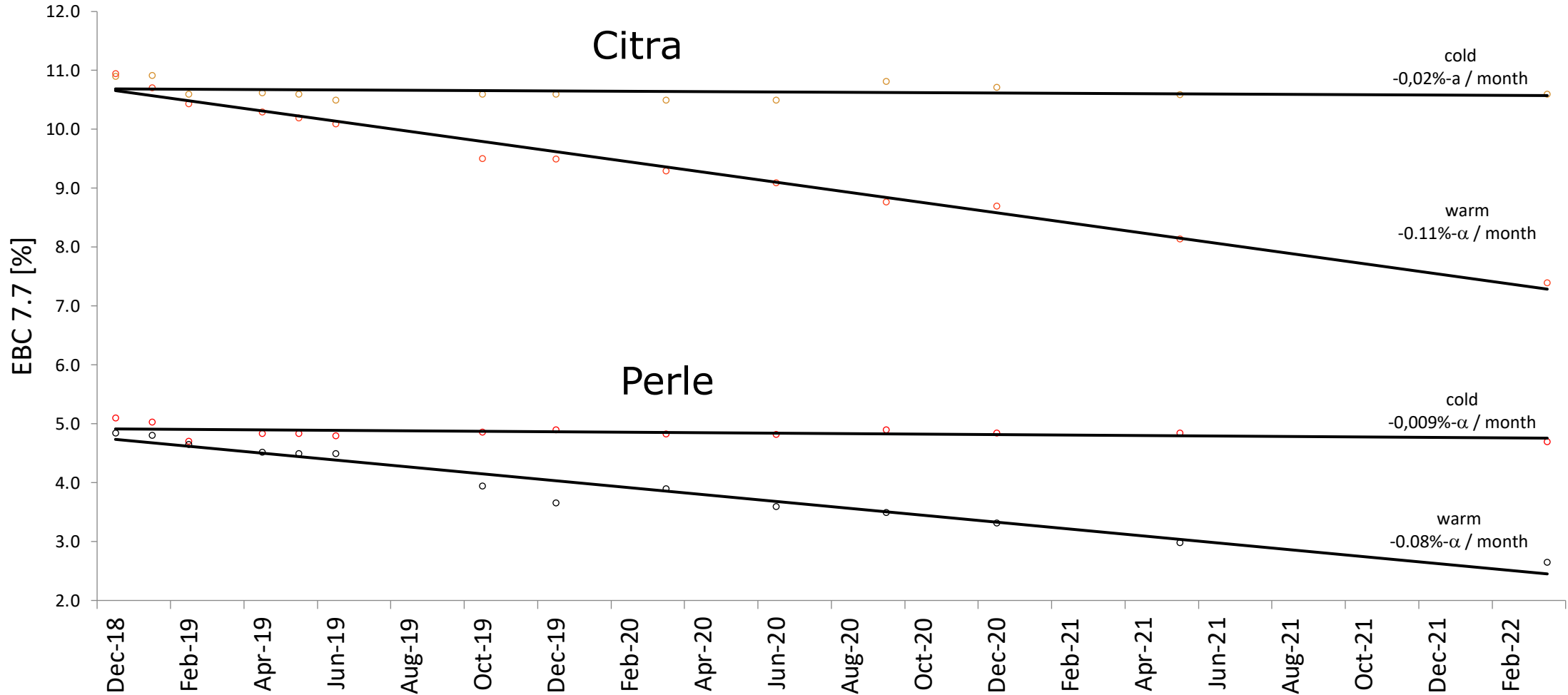
	Cold		
	Dec 2018	March 2022	
Sum of monoterpenes	1261	1091	-13%
Sum of sesquiterpenes	432	423	-2%
Sum of hydrocarbon fraction	1692	1514	-11%
Sum of oxygenated fraction	326	213	-35%
Sum of all esters	212	92	-57%
Sum of monoterpene alcohols and esters	48	52	8%
Sum of sesquiterpene alcohols	50	73	46%
Sum of ketones	43	28	-35%
Sum of epoxides	6	1	-83%



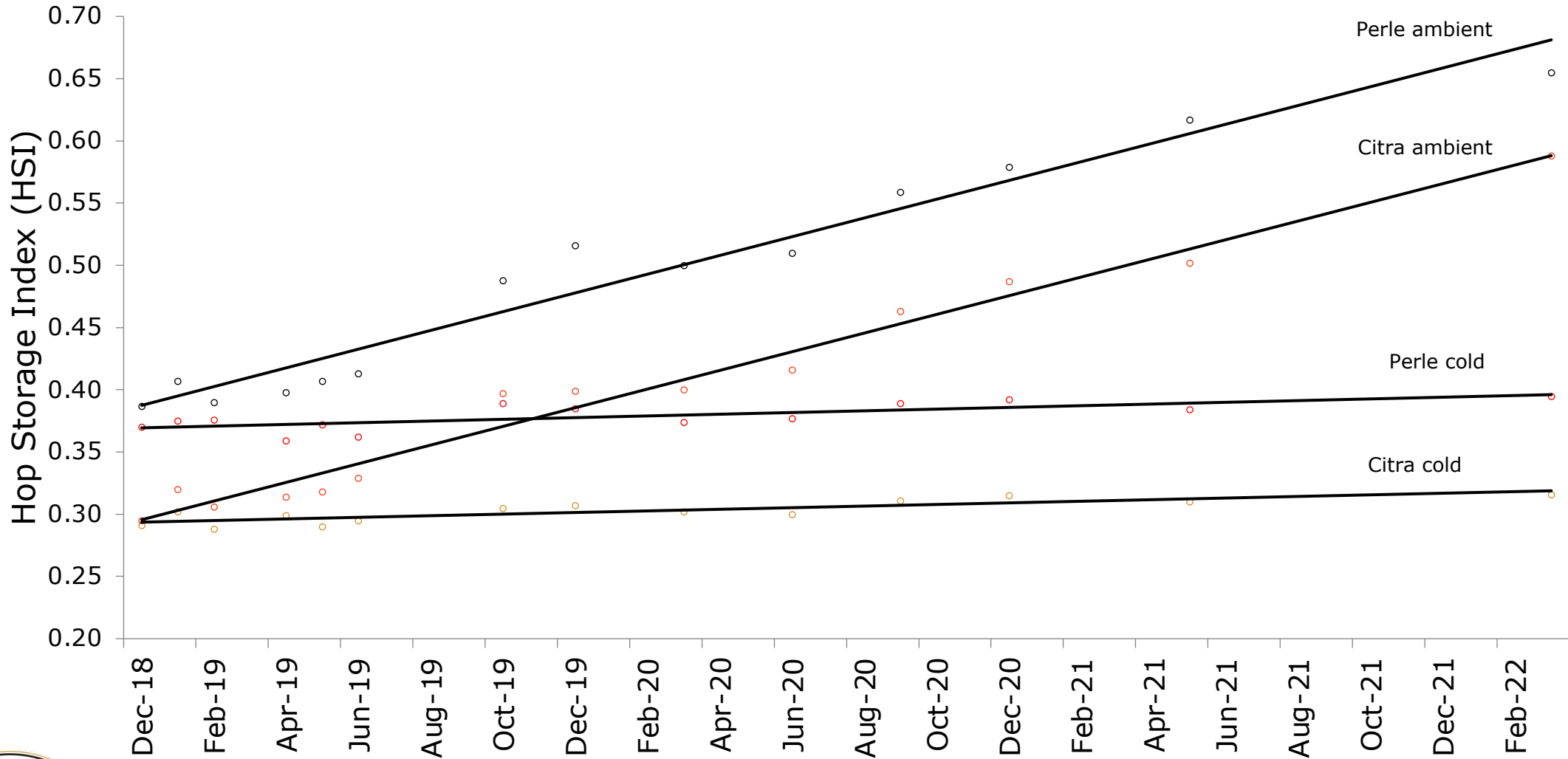


Perle and Citra

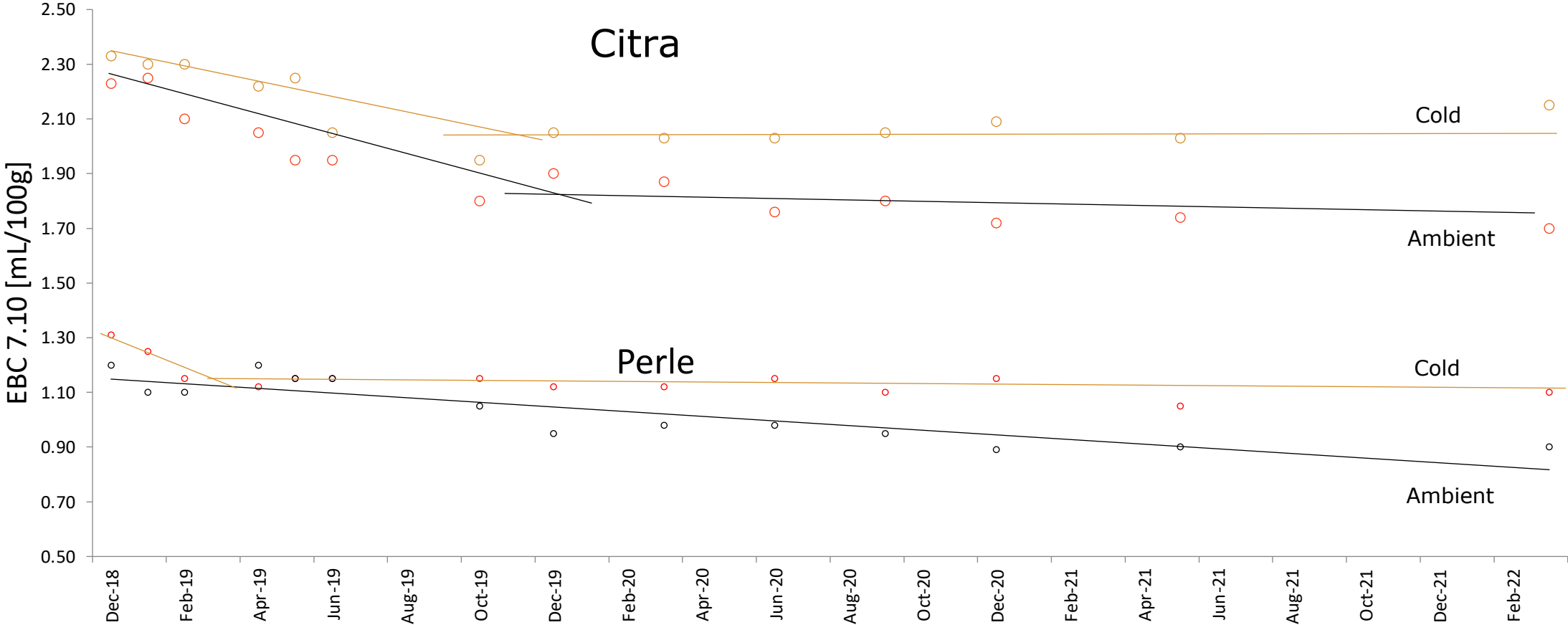
Perle and Citra Alpha-Acids (EBC 7.7)



Perle and Citra Alpha-Acids (HSI)



Citra and Perle Total Oil Content



Perle and Citra

	Perle cold	Perle Ambient
EBC 7.5	-5%	-31%
ASBC		
Alpha in %	-5%	-48%
Beta in %	-3%	-8%
HSI	7%	69%
EBC 7.7		
Cohumulone	-6%	-43%
n + Adhumulone	-9%	-46%
Humulone	-8%	-45%
Colupulone	4%	8%
n + Adlupulone	-4%	-3%
Lupulone	0%	3%
Cohumulone	2%	3%
Colupulone	4%	5%
Total oil	-16%	-25%



Conclusion

- Typical degradation of alpha-acids by UV, LCV and HPLC measurements
- Degradation of valuable components in hop foils is variety dependent
- Total hop oil content over time is hop variety dependent
 - Perle stable
 - Citra stable after one year of storage in foil
- Individual aroma compounds
 - Increase in limonene and farnesene in both hops
 - Cold storage preserves esters
 - Typical oxidation compounds were not found



Acknowledgements

- Bernhard Ramsauer and his team
- John I. Haas
- Scientific community – ASBC and MBAA



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Q & A

ASBC

