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LIQUID CO_2 AND ETHANOL EXTRACTION OF HOPS
Part II—Effect of Hop Deterioration on the Time Course of Extraction

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The time-course of liquid carbon dioxide extraction of fresh and deteriorated hops was compared. The process of extraction becomes more difficult as hops deteriorate, which is reflected by the reduction in the LCV yield (g LCV/kg liquid carbon dioxide used). The extracts derived from deteriorated hops contain higher levels of uncharacterised soft resin. The pattern of elution of the latter does not allow the production of extracts low in uncharacterised soft resins and rich in alpha-acids.

Key Words: *Extraction, deteriorated hops, liquid carbon dioxide, ethanol, extract quality, beer flavour*

Introduction

Studies[1] on the time course of extraction of alpha-acids by liquid carbon dioxide (LCO_2) established that there are two zones with greatly differing rates of extraction. The rate of extraction in the first zone is governed by 'solubility' effects, while in the second zone the rate is limited by 'diffusional' effects. The performance of the process is normally assessed in terms of the extraction efficiency which is the percentage recovery of the available alpha-acids in the hops. During zone (I) extraction, where the majority of the available alpha-acids (*ca* 85%) are usually recovered, the amount of alpha-acids extracted is directly related to the quantity of LCO_2 used. This 'yield' gives an indication of the solvent power of LCO_2 for various feedstocks and process conditions.

This paper describes the time-course of extraction of alpha acids by LCO_2 from varieties of hop with high, medium and low alpha-acids content respectively.

Experimental

See part I of this paper[2].

Results and Discussion

The Effect of Storage on the Degree of Deterioration

Batches of the three hop varieties, Zenith, Challenger and Fuggles with Lead Conductance Values (LCV) at receipt of 9.2%, 6.8% and 5.0% respectively, were stored open to atmosphere at ambient temperature. The LCVs were determined at various intervals (Fig. 1) to establish the extent of deterioration with increased storage. The rates of deterioration were different and was least in the case of Fuggles. While the initial rates of deterioration of Zenith and Challenger were similar, Challenger subsequently deteriorated faster than Zenith.

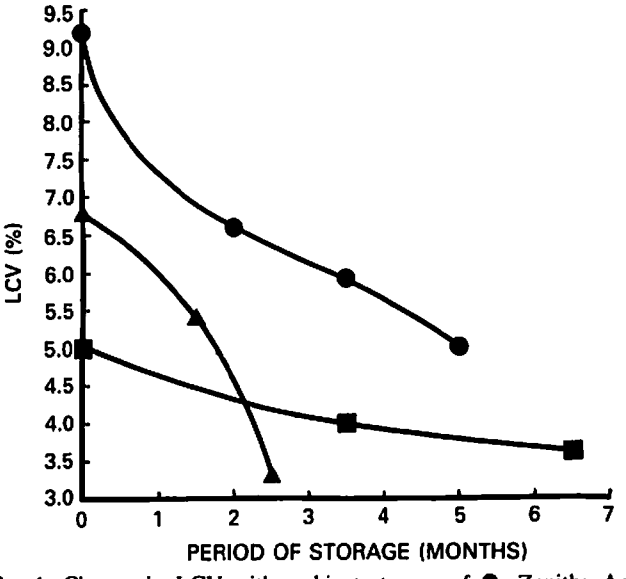

Fig. 1. Change in LCV with ambient storage of ●: Zenith; ▲: Challenger; and ■: Fuggles, hop pellets.

Effect of Deterioration on Extraction Performance

(a) Extraction efficiency

Zenith, Challenger and Fuggles hop pellets, stored at ambient, were extracted with LCO_2 after various intervals. The extraction efficiencies were found to be generally lower as storage progressed, with increased percentage deterioration (Table I). Extraction efficiencies as high as 90% can be obtained if the percentage deterioration of the pellets is less than *ca.* 20%.

TABLE I. Effect of the Degree of Deterioration on LCO_2 Extraction Performance

Hop Variety	Storage Period (Month)	LCV %	Deterioration (%)	Extraction* Efficiency (%)	Zone (I) gLCV/ $kgLCO_2$
Zenith	0	9.2	0	95	5.6
	2	6.6	28	91	4.0
	3.5	5.9	38	87	3.0
	5	5.0	46	83	2.6
Challenger	0	6.8	0	93	3.5
	1.5	5.4	21	89	2.8
	2.5	3.3	51	71	1.5
Fuggles	0	5.0	0	95	3.4
	3.5	4.0	20	89	2.5
	6.5	3.3	28	78	2.6

* Based on LCV at time of extraction

(b) Time course of extraction

It was established previously[1] that, for fresh hops, completion of Zone (I) extraction (i.e. when the extraction becomes limited by diffusional effects) requires the use of a specific amount of LCO_2, for all the LCV to be extracted. Consequently, when the same batch size and variety of hops

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