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STUDIES ON THE PRODUCTION OF FUMARIC ACID AND FERROUS FUMARATE*

M. Khurshid Alam Khan, Miss Kaniz Fizza and Gulzar Ahmed

PCSIR Laboratories, Karachi-39

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Optimisation of reaction conditions for hydrochloric acid catalysed isomerisation of maleic anhydride gave fumaric acid in 95% yield. Studies were also carried on the conversion of fumaric acid to the well known antianaemic agent, ferrous fumarate. A pilot plant for the batchwise production of fumaric acid and ferrous fumarate on 20 kg and 10 kg scale respectively is described. Quality control tests on ferrous fumarate show that it conforms to British Pharmacopoea Standards.

Key words: Pilot plant, Fumaric acid, Ferrous fumarate

INTRODUCTION

Fumaric acid finds diverse uses in food products and is a valuable ingredient for extending the shelf life of many types of food products, e.g. powdered beverages [1] pudding powders [2] and refrigerated biscuit doughs [4]. For flavour enhancement it finds use in fruit juice drinks, gelatin desserts and pie fillings [3,4]. It is also a good antioxidant, and prevents the incidence of rancidity in lard, butter, cheese, powdered milk, sausages, roasted nuts and potato chips [5]. Federal Drug Administration of United States [FDA] classifies fumaric acid and its salts as additives permitted in food for human consumption [6]. One important use of fumaric acid is in the manufacture of the well-known antianaemic agent, ferrous fumarate, where fumaric acid is the chief ingredient. Ferrous fumarate is an imported pharmaceutical item. It was therefore considered worthwhile to optimise conditions for the production of fumaric acid as well as ferrous fumarate first on laboratory and then on a pilot plant scale using an abundantly and cheaply available imported raw material, maleic anhydride.

The studies reported here describe a procedure for the catalytic isomerisation of maleic anhydride to fumaric acid using locally available hydrochloric acid [commercial grade]. In the second step these studies have been extended to the pilot plant production of these two products. Analaysis of ferrous fumarate prepared in this manner indicated that it conforms to British and Pakistan Pharmacopoea Standards.

DISCUSSION

Fumaric acid has been obtained on a commercial scale as a by-product during the production of phthalic and maleic anhydrides, by the isomerisation of maleic acid or anhydride with heat or catalysts [10] and also by the fermentation of glucose or molasses with certain strains of *Rhyzopus nigricans* and *Rhyzopus japanicus* [7]. Laboratory scale synthesis of fumaric acid in 50-58% yield has also been reported by the oxidation of furfural with sodium chlorate using vanadium pentoxide as the catalyst [8].

The availability of maleic anhydride cheaply and readily prompted us to investigate its isomerisation to fumaric acid. The isomerisation catalyst used was locally available hydrochloric acid of commercial grade. A workable scheme for the production of fumaric acid and its subsequent conversion to the fumarate is shown in Fig. 1.

The effect of various proportions of hydrochloric acid on the % yield of fumaric acid is shown in Table 1.

By using a mixture of hydrochloric acid and conc. nitric acid a maximum yield of 75% was obtained but after a scale-up of the reaction to ½ kg scale it dropped to 47%, therefore these conditions were found unsuitable for pilot plant production. Use of hydrochloric acid alone was found to be more advantageous giving yields of upto 98% and there was no significant loss of yields on scale up of the process. Experiment 6 was found to give the best yield and was therefore selected for further pilot plant production study.

EXPERIMENTAL

Pilot Plant Production

(a) Fumaric acid. A typical pilot plant is shown in the flow sheet (Fig. 2). It consisted of a 50 litre capacity glass flask A with heating arrangement, which is connected by a glass tube to a 100 litre capacity glass reaction vessel B fitted with a condenser E and steam heating arrange-

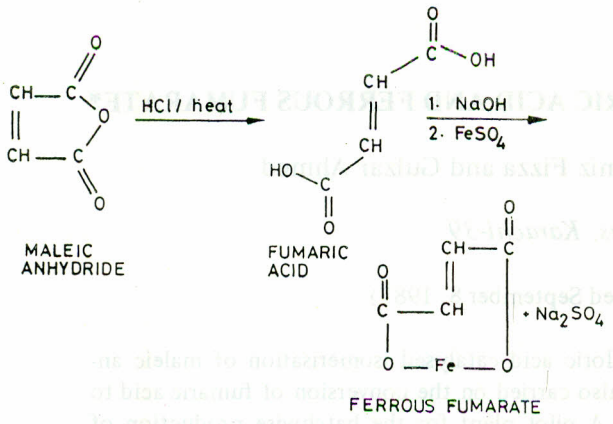

Fig 1.

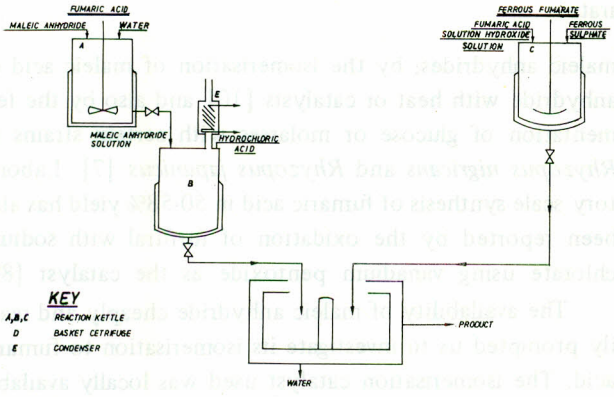

Fig. 2.Flow diagram for (fumaric acid and ferrous fumarate)

Table 1.

S. No.	Maleic anhydride (g)	Water (ml)	65% Conc. HNO_3 (ml)	32% Conc. HCl (ml)	Fumaric acid (% yield)
1.	10	16	0.1	1	75
2.	100	160	1	10	60
3.	500	800	5	50	48
4.	10	10	–	10	98
5.	10	10	–	5	90
6.	1200	1200	–	600	89

ment. The outlet of vessel B fits into a bucket type centrifuge D.

In a typical experiment maleic anhydride (20 kg) was charged in vessel A and was dissolved in water (20 litres) by warming the solution. It was then allowed to flow into the reaction vessel B and 32% hydrochloric acid (commercial) was added. The flask was heated with steam and the solution was refluxed for 3 hr; on cooling to room temperature the bulk of fumaric acid crystallises out. The suspension is allowed to flow in centrifuge D and hydrochloric acid is recovered for reuse. The solid is washed with water till free of HCl and then dried in a hot air oven at 90°. The yield varied from 90-95% in different batches. Fumaric acid had a m.p. of 286-288° which remained undepressed on admixture with an authentic sample. The IR spectrum was superimposable on that of a spectrum of the authentic fumaric acid.

(b) *Ferrous fumarate.* Initially, laboratory studies were carried out. Fumaric acid was converted to the soluble sodium salt by warming with a solution of sodium hydroxide and, while hot the required amount of ferrous sulphate was added. Addition of solid ferrous sulphate was found to be advantageous as it minimises the quantity of ferric iron.

In a typical pilot plant run fumaric acid (8.7 kg) was heated to 90° with a solution of commercial sodium hydroxide (6.0 kg) in water (60 litres) in the reaction vessel C. After all the fumaric acid was dissolved, ferrous sulphate ($FeSO_4.7H_2O$), (21 kg) was added in small portions. The dark brown solid appears in about 20-30 min. After cooling to room temperature it is allowed to flow into centrifuge D; the product is washed with water till free from sodium sulphate. It is dried in an hot air oven at 60°. The yield varied from 65-70% in different batches.

The ferrous fumarate thus obtained was tested for quality according to the methods described in British and Pakistan Pharmacopoea [9a,b]. Ferric iron was $> 2\%$, arsenic > 1 ppm, heavy metals > 1 ppm and sulphate > 10 ppm.

CONCLUSIONS

Maleic anhydride, a cheap and readily available imported intermediate can be converted to fumaric acid by using locally available commercial hydrochloric acid in excellent yield; the recovered HCl can be reused. There is no appreciable loss of yield by scaling up the reaction to a pilot plant scale. Batchwise production of fumaric acid on a 20 kg scale and that of ferrous fumarate on a 10 kg scale can be carried out conveniently on a pilot plant described in this paper. The quality of ferrous fumarate obtained conforms to the British and Pakistan Pharmacopoea Standards.

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