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Protein enrichment of sago starch by solid-state fermentation with *Rhizopus* spp.

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Protein enrichment of sago starch of three different diameters was investigated both in flask culture and under forced aeration in a packed-bed fermenter using two strains of *Rhizopus*. Protein production by *R. oligosporus* UQM 145F was superior to *Rhizopus* sp. UQM 186F in the flask culture without aeration, with both preferring larger diameter (3 to 4 mm) spherical sago-beads. In the packed-bed fermenter with forced aeration, *Rhizopus* sp. UQM 186F led to more rapid protein production compared to *R. oligosporus* UQM 145F and produced equivalent final yields (about 10% protein on a dry wt basis).

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In the year 2000, it is estimated that the world deficit in animal feed protein will be between 65 and 120 million tonnes (Senez 1985). Production of microbial protein from starchy materials has the potential for reducing the deficit in protein production from conventional sources. Sagopalm (*Metroxylon sagu*) is a starch source with significant potential in South-East Asian countries and the Pacific region. At present, there are an estimated 2 million hectares of natural or wild sagopalm, compared to only 200,000 hectares of cultivated sagopalm (Flach 1983).

An economic analysis of protein production from starch revealed that a conventional, aseptic liquid fermentation system is not viable (Senez 1985; Carrizalez & Jaffe 1986; Daubresse *et al.* 1987; Yang 1988). Solid-state fermentation (SSF) on the other hand may have greater potential, because of its simpler production methods and, particularly, its reduced drying costs.

The aim of this study is to produce a monogastric animal feed containing both starch (for its calorific value) and protein. *Rhizopus* was chosen because it has been used in the Indonesian diet for many centuries (Wang & Hesseltine 1982). This fungus contains a relatively high protein content of high biological value (Waliszewska *et al.* 1983) and exhibits significant protein productivity with cassava (Ramos-Valdivia *et al.* 1983; Sukara & Doelle 1988) as substrate.

Materials and Methods

Micro organisms

Rhizopus oligosporus UQM 145F and *Rhizopus* sp. UQM 186F were from the Culture Collection, Department of Microbiology, University of Queensland, Australia. They were maintained following the method of Mitchell *et al.* (1986) replacing cassava starch with sago starch.

Preparation of Substrates

Spherical beads, 2, 3 and 4 mm diameter, of sago substrate were supplied by Bogor Agricultural University, Indonesia. They were examined individually and also in combination: each sago-bead size comprised one-third of the total weight.