Nutritional Quality of Feed Ingredients

Upgradation by Solid State Fermentation (SSF)

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Nutritional security, although a part of food security has a distinct significance. While agriculture provides food security for the people, fish culture has the potential to provide nutritional security too to them. While fish is a rich source of animal protein, it has also essential minerals and vitamins for human nutrition. Further, fish is relatively cheaper, compared to other protein sources.

Of late, aquafarming activities are becoming more popular in India, playing an important role in the socio-economic development of its people, particularly the weaker sections. One constraint is that aquafarming activities being feed centered, its feed costs come to as much as 60-70% of total operational costs. Despite this, the inclusion of quality feed ingredients containing protein, lipid, carbohydrates, vitamins and minerals in correct proportion while preparing feed, is inevitable. In any case, feed stuffs of animal origin which are rich in protein and of high nutritional value are generally expensive and are also becoming scarce over years.

In this background, research on farm-oriented feed preparation to work out formulae to reduce the feed cost without affecting the nutritional requirements of farmed animals and to enable increased utilisation of dietary nutrients has become imperative. For reducing the feed cost, thus, a feed producer has to now depend on plant based ingredients as an alternative source. Plant ingredients are however known to contain less of nutritional value, besides having antinutritional factors. Fortunately, there is a way of enhancement of nutritional values of plant based feed ingredients, and this is through solid state fermentation using suitable micro organisms. Thus application of improved knowledge in fish nutrition for the production of quality feed has to be mandatory.

What is Solid State Fermentation?: Solid State Fermentation (SSF) is a process in which micro-organisms are grown on solid materials with less of water needs. Solid state fermentation can be a tool for biotechnological conversion of agricultural residues to improve digestibility and feed value that can impart better growth performance to fishes as in the case of other animals. Recently SSF has gained interest due to its importance in production of novel feed and feed ingredients with improved amino acid profile, enriched with enzymes, vitamins and other bio-active compounds (Tengerdy, 1996, Viccini *et al*, 2001). Factors like moisture content in the substrate, nature of micro-organisms, oxygen supply and carbon dioxide removal and temperature play major roles in solid state fermentation.

Advantages of SSF: These are: 1) It uses less of water, needs only a small fermenter to synthesise the desired product; 2) It is convenient to go for solid state fermentation as it is a simple biotechnological tool for enriching the substrate; 3) The product concentration becomes higher making it easy to purify the product; 4) The chances of contamination are reduced; 5) It improves digestibility of feed stuffs and maximises the assimilation; and 6) It improves aroma and palatability of the feed ingredients.

Industrial Application of Solid State Fermentation: Applications of SSF for animal feed production include not only to those related to improvement in digestibility, but also to those that would increase bio-availability of nutrients and to those that would increase protein value of feed stuffs. Solid state fermentation improves aroma of the feed ingredients which act as an attractant and taste enhancer. The fermented substrates which become rich in protein, with improved amino acid profile, enriched with desired profile of fatty acids and vitamins, can be used entirely as animal feed (Singh, K. *et al* 1990., Mitra, P. *et al* 1996).

Many workers have tried with various substrates with a numerous number of micro-organisms to identify an efficient micro-organism capable of converting low value agro-wastes to make valuable feed ingredients to produce high value products like enzymes and vitamins.

Some workers have reported that by using *Rhizophus oligospores*, *Trichoderma resei*, and lignocellulosic materials, agro wastes can be improved by SSF to make them suitable to serve as feed ingredients with enhanced protein concentration. Gabriella *et al* (1997) also reported that protein digestibility of wheat bran was increased even upto 82% by solid state fermentation using fungus *Lentinula edodes*. Further, the same fungus also helps in the production of phytase which is an essential enzyme that makes inorganic phosphorus available for metabolism.

Arora *et al* (2000) have reported the two fold increase in true protein from 8.5% in an unfermented sample of potato waste to 13.8% in a fermented one by using *Rhizopus oryza*. The SSF of soybean flour using *Bacillus coagulans* improved the protein and NFE contents of the substrate, along with reduction in crude fibre. The efficacy of the fermented product as fish meal substitute in the diet of post larvae of *Penaeus monodon* was reported by Imelda-Joseph and Paulraj (2003). In another study of SSF of oilcakes using *Aspergillus niger* (Strain 616), and *Bacillus coagulans* resulted in enrichment of protein, and the fermented product was effective as fishmeal replacement (20%) in shrimp diets (Vijayakumar, 2003).

SSF also holds a tremendous potential for production of enzymes. A large no of micro-organisms including bacteria, yeast, and fungi produce a variety of enzymes by solid state fermentation. The crude fermented product can also be used directly as an enzyme source (Pandey *et al*, 1999). It has been found that wheat bran having a crude protein content of 14-16% can be improved by SSF using *Aspergillus niger* to get a crude protein content of 24-27% which is almost 100% more enriched (Bhatnagar, 2004) as may be seen from Table 1.

Table 1: Composition of Raw Wheat Bran and Dried Fermented Wheat Bran using 2 × 10⁶ Spores (on dry matter basis)

Days	Crude Protein	Crude Ash	AIA *	Crude Fat	Total CHO**
Wheat bran	17.03 ± 0.06	3.77 ± 0.02	0.32 ± 0.00	4.96 ± 0.06	73.89 ± 0.61
0	17.60 ± 0.12	5.03 ± 0.00	0.10 ± 0.00	1.74 ± 0.03	75.63 ± 0.32
1	18.38 ± 0.10	5.27 ± 0.02	0.18 ± 0.00	2.18 ± 0.01	74.17 ± 0.29
2	19.36 ± 0.12	5.90 ± 0.01	0.33 ± 0.00	2.85 ± 0.03	71.89 ± 0.36
3	20.94 ± 0.05	6.91 ± 0.01	0.38 ± 0.00	3.09 ± 0.00	69.15 ± 0.31
4	24.61 ± 0.06	7.54 ± 0.03	0.29 ± 0.00	2.75 ± 0.05	65.10 ± 0.31
5	24.76 ± 0.08	8.21 ± 0.16	0.41 ± 0.00	1.69 ± 0.06	65.34 ± 0.60
6	27.62 ± 0.07	8.08 ± 0.00	0.57 ± 0.00	1.46 ± 0.03	62.84 ± 0.38
7	26.39 ± 0.09	8.17 ± 0.06	0.14 ± 0.00	1.01 ± 0.13	64.43 ± 0.38
8	26.25 ± 0.09	8.22 ± 0.02	0.37 ± 0.00	1.03 ± 0.03	64.50 ± 0.62

*Acid in soluble ash, ** Carbohydrates source: (Bhatnagar, 2004).

Aspergillus niger used in SSF produces 19 different types of enzymes on wheat bran. Amylase is one of these, which has got very profuse use in food processing industry, paper industry, and in textiles. *A.niger* collected from mangrove swamps can be used to produce amylase and protease by SSF (Bhatnagar, 2004).Thus amylases in ingredients can be used to enhance the feed performances and its digestibility. A large no of processes in the areas of industrial, environmental and food biotechnology utilises enzymes. Hence researchers can also think of supplementing enzyme enriched ingredients in feeds prepared for fishes without denaturing its enzymatic values during the processing.

SSF improves the palatability of the feedstuffs. Solid state fermentation can be an attractive method for biological treatment of lignocellulosic materials to improve their digestibility to facilitate their enzymatic hydrolysis. Many micro-organisms can grow on solid substrates but growth on solid substrates is a typical property of filamentous fungi that decay organic matter. The use of SSF processes for increasing the digestibility of ligno-cellulosic agricultural residues can be the best way especially due to the direct applicability of fermented product for feeding. So researchers should try to find a way to replace the quantum of fish meal in terms of improved amino acid profile. If it can be achieved, the feed cost can be minimised to a great extent. This can maximise returns.

The solid substrates like wheat bran, rice bran, dried aquatic weed and other feed ingredients should be milled for increasing the surface to volume ratio and to get a better condition for microbial attack. Then the solid substrate has to be moistened with water to a certain extent (50-60%) but it should not release any free water. After moisturisation the substrate has to be sterilised by autoclaving. Then inoculation has to be carried out with spores of fungi or bacteria. SSF should be carried out upto a certain duration to get optimum yield of desired neutraceuticals, enzymes and protein with enhanced amino acid profile.

Conclusion: In view of the anticipated protein shortages globally, micro-organisms offer a variety of possibilities for increased protein production. No doubt microbial proteins have a high nucleic acid content, but studies have shown that their use in animal feed will not cause any problem. This technique can be effectively used for bioconversion of cheaper agricultural by-products to be used in aqua feed as minor/major ingredients, based on the nutritional requirements of the culture organisms. Screening of safe micro-organisms for high protein production and the biotechnological technique to produce better strains of micro-organisms are also suggested as a future approach. In particular, solid state fermentation technology seems to be more appropriate for transferring to rural areas since it entails low cost and requires not much of environmental control.

References

ARORA, M., SEHGAL, V. K. and THAPAR, V. K., 2000. Production of fungal protein and amylases by solid substrate fermentation of potato-waste. *Indian. J. Microbiol.*, **40**: 259-262.

BHATNAGAR, D.D. 2004. Production of amylase and protease by solid state fermentation using *Aspergillus niger* from mangrove swamp. M.F.Sc. (Mariculture) Dissertation, Submitted to Central Institute of Fisheries Education, Mumbai, India.

GABRIELLA, D.L., ELVIRA, P., QUAGLIA, G.B. 1997. Improving the nutritional value of wheat bran by white rot fungus. *International J. of food sci. and tech.*, **32**: 513-519.

IMELDA JOSEPH and PAULRAJ, R. 2003. Fermented soybean flour as a fishmeal substitute in diets of juvenile tiger shrimp, *Penaeus monodon*. In: National Conference on Aquaculture Nutrition, NATP & CMFRI, Kochi, Abst. **20**: 51-53.

MITRA. P., CHAKRABORTY. R. and CHANDRA, A. L., 1996. Production of proteolytic enzymes by solid state fermentation. *J. Sci. Ind. Res.*, **55**: 439-442.

PANDEY, A., SELVAKUMAR, P., SOCCOL, C.R. and NIGAM, P. 1999. Solid state fermentation for the production of industrial enzymes. *Current Sci.*, 77(**1**): 149-162.

SINGH, K., LINDEN, C. J., JOHNSON, E. J. and TENGERDY, P. R., 1990. Bioconversion of wheat straw to animal feed by solid substrate fermentation or ensiling. *Indian J. Microbiol.*, 30(**2**):201-208.

TENGERDY, R.P., 1996. Cellulose production by solid substrate fermentation. *J.Sci. Ind. Res.*, **55**: 313-316.

VICCINI, G., MITCHELL, D.A., BOIT, S.D., GERN, J.C., DA ROSA, A.S., COSTA, R. M., DALSENTER, F.D.H., VON MEIEN, O.F. and KREIGER, N., 2001. Analysis of growth kinetic profile in solid- state fermentation. *Food Technol. Biotechnol.*, **39**: 40, A-B.

VIJAYAKUMAR, 2003. Solid state fermentation of oil cakes and wheat flour and evaluation of the products in shrimp feed, M.F.Sc. (Mariculture) Dissertation, Submitted to Central Institute of Fisheries Education, Mumbai, India, 85p.