# INTISARI

**Integrasi Teknologi Fermentasi dan Nanopartikel Produk Samping Spirulina (*Arthrospira platensis*) untuk Meningkatkan Pertumbuhan dan Kekebalan Ikan Nila Merah (*Oreochromis* sp.)**

Penelitian ini bertujuan untuk meningkatkan kualitas produk samping *Spirulina* melalui dua pendekatan teknologi, yaitu fermentasi mikroba dan nanoteknologi, serta mengevaluasi manfaatnya sebagai suplemen pakan ikan. Metode penelitian meliputi produksi *Spirulina* terfermentasi (FSp) menggunakan bakteri *Bacillus subtilis* dan *Lactococcus formosensis*, serta sintesis Nano-Spirulina (NPS) menggunakan *planetary ball milling*. Kedua produk diuji karakteristik fisikokimianya dan diaplikasikan untuk suplementasi pakan ikan nila merah selama 60 hari untuk menganalisis performa pertumbuhan, efisiensi pakan, dan sistem kekebalan. Data kuantitatif dianalisis secara statistik dan disajikan sebagai nilai rerata±standar deviasi.

Hasil penelitian menunjukkan fermentasi selama 4 hari menghasilkan kadar protein tertinggi sebesar 67,61%, atau meningkat 5,42%, sementara kandungan asam amino esensial meningkat sebesar 3,93% ($P<0,05$). Sintesis nano-Spirulina menggunakan *planetary ball mill* selama 2 jam mampu menghasilkan NPS berukuran 110,43±2,29 nm dan zeta potensial sebesar 31,13±0,17mV. Pada uji pakan, suplementasi FSp dosis 7,5% memberikan hasil terbaik pada pertumbuhan, dibandingkan kontrol ($P<0,05$), dengan performa yang lebih baik dibandingkan pakan komersial. Suplementasi FSp 7,5% menghasilkan nilai FCR terendah sebesar 1,07. Suplementasi FSp juga meningkatkan luas area vili dan sel goblet, serta sistem kekebalan seperti total leukosit, limfosit, aktifitas dan indeks fagositosis, SOD, respiratory burst, lisosim, dan TPP secara signifikan ($P<0,05$). Suplementasi NPS 5% menunjukkan nilai pertumbuhan paling tinggi dibanding dengan pakan uji lainnya ($P<0,05$), dan dosis terkecil suplementasi NPS 1% sudah mampu menghasilkan pertumbuhan dan FCR yang lebih baik dibandingkan pakan komersial ($P<0,05$). FCR terendah ditunjukkan pada suplementasi NPS 5% yaitu sebesar 1,00, NPS 1 % sebesar 1,14, sementara pakan komersial memiliki FCR 1,19. Suplementasi NPS juga dapat meningkatkan kapasitas pencernaan dan sistem imun ($P<0,05$). Diantara suplementasi FSp dan NPS tidak memberikan perbedaan yang signifikan terhadap SR dengan presentase 87-89% ($P>0,01$). Penggunaan NPS 5% memberikan hasil teknis terbaik dengan masa panen paling singkat, yaitu 136 hari atau mampu mempercepat masa panen hingga 32 hari lebih awal dibandingkan pakan komersial. Sementara, FSp 7,5% mempercepat panen hingga 11 hari. Secara umum, pemanfaatan produk samping Spirulina melalui teknologi fermentasi dan nanoteknologi efektif meningkatkan pertumbuhan, kapasitas pencernaan, dan sistem kekebalan ikan nila merah.

**Kata Kunci:** Fermentasi, Nanoteknologi, Nano-Spirulina, *Oreochromis* sp., Pertumbuhan, Imunitas.

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# ABSTRACT

## Integration of Technology in Fermentation and Nanoparticles of Spirulina (*Arthrospira platensis*) By-Products to Improve Growth and Immunity of Red Tilapia (*Oreochromis* sp.)

This study aimed to improve the quality of Spirulina by-products through two technological approaches: microbial fermentation and nanotechnology, and to evaluate their benefits as fish feed supplements. The research methods included the production of fermented Spirulina (FSp) using Bacillus subtilis and Lactococcus formosensis bacteria, and the synthesis of Nano-Spirulina (NPS) using planetary ball milling. Both products were tested for their physicochemical characteristics and applied as feed supplementation to red tilapia for 60 days to analyze growth performance, feed efficiency, and immune system function. Quantitative data were statistically analyzed and presented as mean ± standard deviation.

The results showed that 4 days of fermentation produced the highest protein content of 67.61%, an increase of 5.42%, while essential amino acid content increased by 3.93% ($P<0.05$). Synthesis of nano-Spirulina using a planetary ball mill for 2 hours was able to produce NPS measuring 110.43±2.29 nm and a zeta potential of 31.13±0.17 mV. In the feed test, FSp supplementation at a dose of 7.5% gave the best results on growth, compared to the control ($P<0.05$), with better performance than commercial feed. 7.5% FSp supplementation produced the lowest FCR value of 1.07. FSp supplementation also increased the area of villus and goblet cells, as well as the immune system such as total leukocytes, lymphocytes, phagocytosis activity and index, SOD, respiratory burst, lysozyme, and TPP significantly ($P<0.05$). 5% NPS supplementation showed the highest growth value compared to other test feeds ($P<0.05$), and the smallest dose of 1% NPS supplementation was able to produce better growth and FCR than commercial feed ($P<0.05$). The lowest FCR was shown in 5% NPS supplementation, which was 1.00, 1% NPS was 1.14, while commercial feed had an FCR of 1.19. NPS supplementation can also improve digestive capacity and the immune system ($P<0.05$). Between FSp and NPS supplementation did not provide a significant difference in SR with a percentage of 87-89% ($P>0.01$). The use of 5% NPS provided the best technical results with the shortest harvest period, namely 136 days or was able to accelerate the harvest period up to 32 days earlier than commercial feed. Meanwhile, 7.5% FSp accelerated the harvest by up to 11 days. In general, the utilization of Spirulina by-products through fermentation technology and nanotechnology effectively increases the growth, digestive capacity, and immune system of red tilapia.

Keywords: Fermentation, Nanotechnology, Nano-Spirulina, Oreochromis sp., Growth, Immunity

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