

**EVOLUTIONARY ALGORITHMS WITH AVERAGE  
CROSSOVER AND POWER HEURISTICS FOR  
AQUACULTURE DIET FORMULATION**

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## Abstrak

Industri penternakan akuakultur merupakan salah satu industri yang paling penting di Malaysia kerana ia menjana pendapatan kepada pertumbuhan ekonomi dan menghasilkan sumber makanan utama kepada negara. Salah satu tunggak dalam industri penternakan akuakultur merupakan formulasi diet makanan untuk haiwan, yang juga dikenali sebagai kombinasi atau formulasi bahan makanan. Walau bagaimanapun, kos operasi komponen pemakanan dalam industri akuakultura adalah yang paling mahal kosnya, dan ini menyebabkan banyak kajian dijalankan berkaitan formulasi diet. Kekurangan kajian yang melibatkan pembinaan model telah memberikan motivasi untuk mengkaji formulasi diet, iaitu mencari kombinasi terbaik daripada bahan makanan yang dapat memenuhi keperluan pemakanan dengan kos yang minimum. Oleh itu, tesis ini mengkaji penggunaan Algoritma Evolusi (EA) bagi mencadangkan penyelesaian formulasi diet untuk penternakan akuakultur, khususnya udang. Dalam usaha untuk mendapatkan kombinasi bahan yang terbaik, kaedah penapisan heuristik yang dikenali sebagai Heuristik Kuasa diperkenalkan di peringkat pemulaan dalam metodologi EA. Ia berupaya menapis beberapa bahan yang tidak diinginkan daripada senarai bahan pilihan yang telah dikenalpasti daripada pangkalan data, yang mana ia boleh membawa kepada satu penyelesaian yang tidak diinginkan. Kejayaan model EA yang dicadangkan ini juga bergantung kepada operator baharu bagi pemilihan dan penyilangan, yang dapat meningkatkan prestasi penyelesaian secara keseluruhan. Tiga model utama EA telah dibangunkandengan mekanisma pemulaan yang baharu, serta operator pemilihan dan operator penyilangan yang pelbagai. Keputusan kajian mendapati model EA-PH-RWS-Avg adalah yang paling berkesan dalam memberikan hasil penyelesaian terbaik dengan nilai penalti paling minimum. Model baharu yang dicadangkan ini adalah efisien dan mampu disesuaikan dengan perubahan dalam parameter, justeru dapat membantu pengguna menyelesaikan masalah berkaitan formulasi diet udang, khususnya menggunakan bahan tempatan. Selain itu, strategi formulasi diet ini juga menyediakan elemen berasaskan pilihan pengguna untuk menentu bahan pilihan makanan dan jumlah berat bahan yang sesuai.

**Kata Kunci:** Algoritma evolusi, Heuristik kuasa, Operator penyilangan purata, Formulasi diet, Kombinasi pemakanan

## Abstract

The aquaculture farming industry is one of the most important industries in Malaysia since it generates income to economic growth and produces main source of food for the nation. One of the pillars in aquaculture farming industries is formulation of food for the animal, which is also known as feed mix or diet formulation. However, the feed component in the aquaculture industry incurs the most expensive operational cost, and has drawn many studies regarding diet formulation. The lack of studies involving modelling approaches had motivated to embark on diet formulation, which searches for the best combination of feed ingredients while satisfying nutritional requirements at a minimum cost. Hence, this thesis investigates a potential approach of Evolutionary Algorithm (EA) to propose a diet formulation solution for aquaculture farming, specifically the shrimp. In order to obtain a good combination of ingredients in the feed, a filtering heuristics known as Power Heuristics was introduced in the initialization stage of the EA methodology. This methodology was capable of filtering certain unwanted ingredients which could lead to potential poor solutions. The success of the proposed EA also relies on a new selection and crossover operators that have improved the overall performance of the solutions. Hence, three main EA model variants were constructed with new initialization mechanism, diverse selection and crossover operators, whereby the proposed EA-PH-RWS-Avg Model emerged as the most effective in producing a good solution with the minimum penalty value. The newly proposed model is efficient and able to adapt to changes in the parameters, thus assists relevant users in managing the shrimp diet formulation issues, especially using local ingredients. Moreover, this diet formulation strategy provides user preference elements to choose from a range of preferred ingredients and the preferred total ingredient weights.

**Keywords:** Evolutionary algorithm, Power heuristics, Average crossover operator, Diet formulation, Feed mix

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## List of Abbreviations

ABC	Artificial Bee Colony
AI	Artificial Intelligence
BCGA	Binary Coded Genetic Algorithm
BSI	Bee Swarm Intelligence
CCP	Chance Constrained Programming
DOF	Department of Fisheries
DP	Dynamic Programming
DSS	Decision Support System
EA	Evolutionary Algorithm
EAA	Essential Amino Acids
FAO	Food and Agriculture Organization
FLP	Fuzzy Linear Programming
GA	Genetic Algorithm
GP	Goal Programming
GUI	Graphical User Interface
IFAH	International Federation for Animal Health
LP	Linear Programming
MCDM	Multi Criteria Decision Making
MCS	Monte Carlo Simulation
MOFP	Multi Objective Fractional Programming
MOP	Multi Objective Programming
MGP	Multi Goal Programming
NLP	Nonlinear Programming
NRC	National Research Council
OR	Operations Research
PSM	Pearson's square method
QP	Quadratic Programming
RCGA	Real Coded Genetic Algorithm
RPV	Roulette penalty value
RF	Risk Formulation
RT	Roulette-Tournament



RWS	Roulette Wheel Selection
SAE	Simultaneous Algebraic Equations
Sec	Second
TE	Trial and Error method
QB	Queen-Bee

# **CHAPTER 1**

## **INTRODUCTION**

Animal source food is important for humans to avoid malnutrition since it provides a lot of nutrients needed by a human body often limited in a diet (Demment, Youngy, & Sensenig, 2003; Neumann, Harris, & Rogers, 2002). These nutrients include protein, iron, vitamin, carbohydrate, potassium and sodium, which contribute in generating new tissues and producing energy, and have diversified benefits to humans. However, only healthy aquaculture can provide healthy food in adequate quantity for human consumption (Hansard Team Kenya National Assembly, 1993; International Federation for Animal Health [IFAH], 2011). Among the animals that contribute a good source of food are fish, mussels and shrimps.

### **1.1 Challenges in aquaculture industry**

Growth in the world population has increased demand for healthy animal source food including aquaculture produce. As captured aquacultures can no longer meet the high market demand, the farming industry is forced to increase the production of farmed animals to fulfil the current needs. Like other industries, the main objective of a food producing industry is to generate maximum income and profit. Therefore, farmers have to strategize in order to minimize their production costs and sell their produce at the highest possible price. In addition to market demand and size, farmed animal price depends on its appearance such as stress and unhealthy eyes (Blue et al., 2007). Sufficient nutritional need is important to obtain good appearance and healthy body, thus contributing to a higher sale market value. Farmers need to provide enough nutritious food to ensure that their farmed animals receive adequate nutrition.

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