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# A Modified Linear Programming Model for Cost Minimisation of *Pangasius Hypophthalmus* Feed Formulation

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**ABSTRACT**

*Pangasius hypophthalmus or P.hypophthalmus is a common freshwater species cultured in Malaysia. Problems arise among farmers as the commercial pellets or feeds are too expensive. There is a limitation on the affordability of the farmers on the existing feed formulation due to its high and rising prices. In addition, there is no specific commercial pellet that is specifically designed to fulfil the nutrient requirement of P.hypophthalmus. Hence, this study is aimed to modify a linear programming model and propose the most optimum amount of nutrients in P.hypophthalmus feed formulation at each life cycle at minimum production cost, based on the solution of the modified model. The data on the nutrient requirement and ingredient composition for every life stage of P.hypophthalmus were gathered through literature and websites. The main ingredients used in the fish feed formulation are shrimp head flour, soybean meal, fish meal, cinnamon leaf powder, brewers' spent grain, wheat pollard, rice bran and wheat flour. The novelties of the modified linear programming model are the inclusion of all four life stages of P.hypophthalmus in a single model, and the addition of a new supplement ingredient that is able to enhance the growth of P.hypophthalmus. The optimal solution revealed that the minimum production costs per 150 kg of feed mix for all four life stages are RM228.80, RM379.90, RM231.80 and RM233.10, respectively. The total price for the feed formulation is reduced by 26% to 37% as compared to the commercial feed price.*

**Keywords:** *linear programming; feed formulation; P.hypophthalmus; freshwater species; life stages.*

## 1. INTRODUCTION

Fish farming is one of the most economically significant sectors in Malaysia. *Pangasius hypophthalmus* (*P.hypophthalmus*) or known as *Patin Hitam* by local Malaysians, is one of the most important food sources in Malaysia [1]. Over the last three decades, *P.hypophthalmus* farming has recorded a remarkable growth that it has become a global icon of aquaculture development with production and export levels corresponding to tilapia, carps and salmon [2-3]. *P.hypophthalmus* is one of the nourishing freshwater fish [4]. The striped catfish meat contains the least heavy metals as compared to other fish meat, including sea fish [5-7]. Other findings also show that this species has been accepted in many countries and the global market for striped catfish flesh appears to be increasing [6], [8]. Moreover, Molnár et al. [9] claimed that *P.hypophthalmus* is proven to be the best species to be cultured in a cage. Figure 1 shows the picture of a *P.hypophthalmus*.

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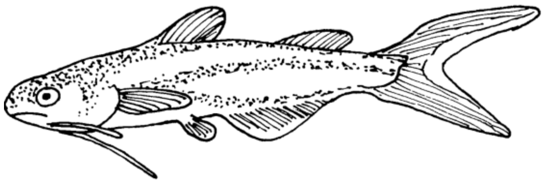

Figure 1: A P.hypophthalmus [10]

Since fish feed contributes the biggest cost in most fish farming, the selection of food ingredients used in feed mixtures plays an important role in determining its overall nutritional and economic performance [11]. Feed formulation is a process in which multiple ingredients are mixed together to provide adequate nutrients to animals at different life cycle stages. A good feed should provide all essential nutrients and energy to secure the body systems of animal growth, reproduction and health. The composition of feed, the requirement of particular nutrients, and the financial limitation are the essential aspects of animal feed formulation. Some traditional approaches have been used to improve feed efficiencies, such as the trial and error method, simultaneous equation method, square method, two-by-two matrix method and fixed formulation method. However, these methods have an inflexibility of a defined quantity and do not opt for reducing the objective cost [12]. Despite the traditional methods to improve feed efficiency, nutritionists have clarified that animals will consume food in the most productive way when the nutrients provided in daily feeds are the same as their daily needs.

The commercial farming of *P.hypophthalmus* in Malaysia started in the 1970s but the defined nutritional growth requirement for *P.hypophthalmus* shows a knowledge gap for adequate dietary formulation due to a lack of data and evidence [13]. Even though striped catfish farming has become a global icon of aquaculture in Malaysia, there is a lack of study on *P.hypophthalmus* feed formulation. Many research focused on feed formulation for other species of freshwater fish, for example, milkfish, tilapia, Asian seabass, common carp and other types of catfish. In general, feeds contribute between 60% and 70% to the operating costs of various species cultured. Thus, the profit margin indirectly depends on the cost of feed of the cultured fish itself. Nonetheless, there is a limitation on the existing formulated feed for small and moderate farmers due to its high and rising prices. Another issue in the freshwater aquaculture sector is that there is no specific feed for *P.hypophthalmus* available on the market. For some reason, many farmers only use raw and unprocessed feed. A study by Jayant et al. [14] stated that one of the major challenges faced in *P.hypophthalmus* farming is the lack of good quality feed. Therefore, it is crucial to obtain a good feed formulation for the sustainability in the freshwater fish aquaculture industry.

The aim of the study is to modify a linear programming (LP) model and propose the most optimum nutrient amount in *P.hypophthalmus* feed formulation at a minimum cost based on the solution of the modified model. In addition to this, the inclusion of cinnamon leaf powder as a supplement in the feed mixture will enhance the growth and feed efficiency of *P.hypophthalmus* [15]. This additional supplement ingredient is one of the novelties in this study. Another novelty is the combination of every life stage of *P. hypophthalmus*, namely fry, fingerling, grower and broodstock in a single LP model.

The model will help the local freshwater fish feed manufacturer to produce the feed at lower expenses yet fulfil the nutritional requirements. This will indirectly help in gaining better profit

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for their business. The results of the study will also be beneficial to *P.hypophthalmus* farmers as cheaper and more nutritious feed for the catfish will be available in the Malaysian market.

## 2. RELATED WORKS

For the past decades, there are various research that were done on fish feed formulation. Ghosh [16] produced three feed formulations for a number of species, namely tiger shrimp juveniles, scampi juveniles, rohu fry, catfish fry, milkfish fry, tilapia fry, Asian sea bass fry and grouper fry. He considered twenty-five ingredients to produce the new feed formulations for each species. Three sets of costs from the Indian local market at Kochi, Tuticorin and Bhubaneswar were considered to achieve the least cost feed formulation for all species. Subsequently, Ghosh et al. [17] extended his study focusing on the fry of widely cultured species in India. In the study, the market price of the ingredients were collected from other places in India. They managed to produce three different feed formulations for the selected species. These feeds are different in terms of the prices and ingredients, due to the cost differences between the local places. In addition to the study, Nath and Talukdar [18] and Aizam et al. [19] produced the least cost feed formulation for carp and catfish, respectively.

Many studies strived to reduce feed cost and propose suitable feeding strategies by improving fish feed utilisation. Taking this as a challenge, Batool et al. [20] have tested the impact of various levels of azomite concentration on the growth performance and body composition of *P.hypophthalmus* fry. Azomite is a very useful natural mineral product found in the USA and also abundantly used in Asia. It is a certified organic trace mineral booster and is used as a supplement in livestock and aquatic animal feeds globally for over a decade. The study has found that the supplement of azomite at 1.0% in the *P.hypophthalmus* fry diet can significantly increase growth without any significant alteration in the fish biochemical nutrient profile when fed with 38.3% of crude protein feed.

Mathematical programming approach is widely used in solving animal feed formulation problems. Studies by [16-19] used LP model to solve animal feed formulation problems. Devani [21] applied multi-objective goal programming (GP) to produce artificial fish feed for freshwater fish. The aim is to identify the nutritional requirements of raw materials for producing quality nutritious fish feed and to reduce the operating costs of freshwater fish farmers. She considered three nutrients in the model which are protein, carbohydrates and fat. Based on the results, a pack of 100 kg of fish feed raw materials are made of 20 kg of protein, 30 kg of carbohydrates and 5.2 kg of fat, while the manufacturing cost was reduced by 20%.

Nath and Talukdar [18] implemented a LP model for feed formulation that result in higher efficiency in fish aquaculture industries. The aim of the study is to generate an optimisation model of feed formulation for the Assam's fish farmers by using local feed ingredients. As a result of the study, more effective feeds were developed using nutrient limitations and data compositions that directly applicable to Assam's conditions and feed ingredients. A general mathematical model for feeding time of the fish was adapted from the fishermen in the Kamrup district. Meanwhile, Aizam et al. [19] applied the LP model to develop a least cost fish feed formulation. The study aimed to identify the best feed combination for two different life stages of catfish, taking nutrient requirement into account. The objective function of the LP model in the study is to minimise the production cost of the feed. As result of the study, the fish feed formulation obtained is found to be cheaper than the commercial feed.

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From the literature reviews, there are many studies done on the feed formulation for freshwater fish, however, the study on the feeding composition for *P.hypophthalmus* is still lacking. Therefore, this study intend to fill this research gap and additionally introduce a new supplement, called cinnamon leaf powder which is good for *P.hypophthalmus* growth.

## 3. METHODOLOGY

In this research, the ingredients used in *P.hypophthalmus* feed formulation were shrimp head flour, soybean meal, fish meal, cinnamon (*Cinnamomun burmannii*) leaf powder, brewers' spent grain, wheat pollard, rice bran and wheat flour. The nutrient content of ingredients was obtained through various resources such as past studies and related websites. The nutrients that are considered in this research are crude protein, crude lipid, ash, crude fibre, carbohydrate and gross energy. The market price of ingredients was compared from several shops in online websites to obtain the lowest price. The nutrients composition of shrimp head flour, soybean meal, fish meal, cinnamon leaf powder, brewers' spent grain, wheat pollard, rice bran and wheat flour are stated in the past studies of [22-28].

A new feed formulation that satisfies specific nutrient requirement of the species is strongly needed as the existing commercial feeds only provide the nutrient for any freshwater species in general. Thus, this study strives to determine a composition of suitable ingredients to supply enough nutrients and energy for every life stage of *P. hypophthalmus*, which are fry, fingerling, grower and broodstock.

A linear programming model is modified based on the reference model by Aizam et al. [19]. The modified linear programming model for *P.hypophthalmus* feed formulation problem in this study is shown as follows.

$$Minimise\ Z = \sum_{j}^{J} \sum_{k}^{K} c_j x_{jk} \tag{1}$$

subject to:

$$\sum_{j}^{J} a_{ij} x_{jk} \geq b_{ik} \quad \forall i, k \tag{2}$$

$$\sum_{j}^{J} x_{jk} = M_k \quad \forall k \tag{3}$$

$$x_{jk} \geq N_j \quad \forall k; j = 4 \tag{4}$$

$$x_{jk} \geq 0 \quad \forall j, k \tag{5}$$

where,

| | | |
|---|---|---|
| *i* | = | index for nutrient *(i = 1,2,...,I)* |
| *j* | = | index for ingredient *(j = 1,2,...,J)* |
| *k* | = | index for *P.hypophthalmus* life stage *(k = 1,2,...,K)* |

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| | | |
|---|---|---|
| $I$ | = | total number of nutrients *(I = 6)* |
| $J$ | = | total number of ingredients *(J = 8)* |
| $K$ | = | total number of *P.hypophthalmus* life stages *(K = 4)* |
| $M_k$ | = | total amount (kg) of feed mixture produced for *k* life stage $(M_k = 150)$ |
| $Nj$ | = | minimum amount (kg) of ingredient *j* needed in the feed mixture $(N_j = 1)$ |
| $a_{ij}$ | = | amount (kg) of nutrient composition *i* in ingredient *j* |
| $b_{ik}$ | = | dietary requirement of nutrient *i* for *P.hypophthalmus* life stage *k* |
| $c_j$ | = | price of ingredient *j* per kg |
| $x_{jk}$ | = | amount (kg) of ingredient *j* used in *k* life stage of *P.hypophthalmus* feed formulation |
| $Z$ | = | minimum production cost of fish feed formulation |

Equation (1) indicates the objective function of the model which represent the minimum cost of fish feed formulation. The aim is to minimise the production cost of *P.hypophthalmus* feed and yet satisfy all nutrients requirement for every life stage of the species. The notation $x_{jk}$ is the model decision variables that represent the amount in kg of ingredient $j$ needed in $k$ life stage feed mixture. Constraint (2) represents the nutrient restriction of fry stage, fingerling stage, grower stage and broodstock stage, respectively. Constraint (3) is an amount restriction constraint which is needed to standardise the end product produced. Constraint (4) is the ingredient restriction constraint. Finally, the non-negativity restriction is represented by Constraint (5).

## 4. RESULTS AND DISCUSSION

Table 1 illustrates the result obtained by solving the LP model. Excel Solver was utilised to generate the optimal solution for the modified LP model. The solutions obtained are the amount of ingredient that optimise the nutrients in *P.hypophthalmus* feed formulation that must be included in the 150 kg of the feed mix of each life stage, as well as the corresponding total cost.

Based on the results, 41.5 kg of soybean meal, 1 kg of cinnamon leaf powder, 75.1 kg of brewers' spent grain and 32.3 kg of wheat pollard are used to formulate 150 kg of fish feed that will satisfy all nutrients requirement of *P.hypophthalmus* fry at a total cost of RM228.80. For the fingerling stage of *P.hypophthalmus*, 81.8 kg of soybean meal, 35.2 kg of fish meal, 1 kg of cinnamon leaf powder, 5.6 kg of brewers' spent grain and 26.3 kg of wheat flour are needed in 150 kg of feed mixture that met all nutrient requirements at the least cost of RM379.90. In addtion to this, it only cost RM231.8 for 150 kg of full nutritious *P.hypophthalmus* grower feed which has the combination of 42.4 kg of soybean meal, 1 kg of cinnamon leaf powder, 91.5 kg brewers' spent grain and 15.1 kg of wheat pollard. Finally, for the broodstock stage, the feed formulation consists of 42.8 kg of soybean meal, 1 kg of cinnamon leaf powder, 99 kg of brewers' spent grain and 7.2 kg of wheat pollard. This feed mixture costs RM233.10 for 150 kg.

Based on the observation on the results obtained, the ingredients used are the same for fry, grower and broodstock stages, which are soybean meal, cinnamon leaf powder, brewers' spent grain and wheat pollard. Soybean meal is selected for every life stage feed formulation due to its low price and high protein content. Meanwhile, fish meal and wheat flour are only selected in fingerling feed as the feed mixture of this stage is different as compared to other life stage feed. However, the quantity of nutrients provided by the selected ingredient are adequate to

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fulfil all requirements at minimum cost. This agrees with the objective of the modified LP model which is to seek for the lowest cost of ingredients while fulfilling other requirements. In addition to this finding, the cost for fingerling stage feed turned out to be slightly higher than the other stage due to high protein content in the feed.

Table 1: The Amount of Ingredient Included in *P.Hypophthalmus* Least Cost Feed Formulation

| Life stage | Ingredient | Amount of ingredient included (kg) | Cost | Total cost (RM/150 kg) |
|---|---|---|---|---|
| Fry | Shrimp head flour | - | - | 228.8 |
| | Soybean meal | 41.5 | 51.5 | |
| | Fish meal | - | - | |
| | Cinnamon leaf powder | 1 | 38 | |
| | Brewers' spent grain | 75.1 | 101.4 | |
| | Wheat pollard | 32.3 | 37.9 | |
| | Rice bran | - | - | |
| | Wheat flour | - | - | |
| Fingerling | Shrimp head flour | - | - | 379.9 |
| | Soybean meal | 81.8 | 101.4 | |
| | Fish meal | 35.2 | 197.3 | |
| | Cinnamon leaf powder | 1 | 38 | |
| | Brewers' spent grain | 5.6 | 7.6 | |
| | Wheat pollard | - | - | |
| | Rice bran | - | - | |
| | Wheat flour | 26.3 | 35.6 | |
| Grower | Shrimp head flour | - | - | 231.8 |
| | Soybean meal | 42.4 | 52.6 | |
| | Fish meal | - | - | |
| | Cinnamon leaf powder | 1 | 38 | |
| | Brewers' spent grain | 91.5 | 123.5 | |
| | Wheat pollard | 15.1 | 17.7 | |
| | Rice bran | - | - | |
| | Wheat flour | - | - | |
| Broodstock | Shrimp head flour | - | - | 233.1 |
| | Soybean meal | 42.8 | 53.1 | |
| | Fish meal | - | - | |
| | Cinnamon leaf powder | 1 | 38 | |
| | Brewers' spent grain | 99 | 133.5 | |
| | Wheat pollard | 7.3 | 8.5 | |
| | Rice bran | - | - | |
| | Wheat flour | - | - | |

Cinnamon leaf powder is the most expensive ingredient used in the new feed for *P.hypophthalmus*. This ingredient acts as a supplement that helps to enhance the growth of the species. A study by Setiawati et al. [15] has stated that the feed enriched by cinnamon leaf powder is effective in enhancing the growth and feed efficiency of the species. Due to the high cost of cinnamon leaf powder, the LP model was run again to investigate the results if the supplement is excluded from the mixed feed formula.

Table 2 shows the *P.hypophthalmus* feed formulation obtained when cinnamon leaf powder was excluded from the ingredient list. It shows the amount of ingredient that must be included in the 150 kg of the feed mix each life stage, that will optimise the nutrients in *P.hypophthalmus*

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feed formulation, together with the corresponding total cost. Keeping the ingredients used in the mixture unchanged, there is a slight difference in the amount of the ingredient used. For fry stage feed, the mixture consists of 41.5 kg of soybean meal, 75.2 kg of brewers' spent grain and 33.3 kg of wheat pollard with the least cost of RM191.90 for 150 kg feed mixture. The price for fingerling stage is RM339.50, which is a little higher as compared to other feed mixture production cost of other life cycles. There are 82.5 kg of soybean meal, 34.4 kg of fish meal, 7.5 kg of brewers' spent grain and 25.6 kg of wheat flour in 150 kg of fingerling stage feed formulation. The ingredients used in 150 kg of grower stage feed formulation without supplement are 42.4 kg of soybean meal, 91.6 kg of brewers' spent grain and 16 kg of wheat pollard for RM194.80. Finally, for the broodstock stage of feed formulation without supplement ingredient, the ingredients included in 150 kg feed mixture are 42.8 kg of soybean meal, 99 kg of brewers' spent grain and 8.2 kg of wheat pollard. The corresponding production cost for this feed mixture is RM196.30. The result shows that the cost of the feed formulation without supplement ingredient is cheaper than the feed formulation with supplement ingredient by 10 to 16 percent.

Table 2: The Amount of Ingredient Included in *P.Hypophthalmus* Feed Formulation without Supplement Ingredient

| Life stage | Ingredient | Amount of ingredient included (kg) | Cost | Total cost (RM/150 kg) |
|---|---|---|---|---|
| | Shrimp head flour | - | - | |
| | Soybean meal | 41.5 | 51.5 | |
| | Fish meal | - | - | |
| Fry | Brewers' spent grain | 75.2 | 101.5 | 191.9 |
| | Wheat pollard | 33.3 | 38.9 | |
| | Rice bran | - | - | |
| | Wheat flour | - | - | |
| | Shrimp head flour | - | - | |
| | Soybean meal | 82.5 | 102.3 | |
| | Fish meal | 34.4 | 192.5 | |
| Fingerling | Brewers' spent grain | 7.5 | 10.1 | 339.5 |
| | Wheat pollard | - | - | |
| | Rice bran | - | - | |
| | Wheat flour | 25.6 | 34.6 | |
| | Shrimp head flour | - | - | |
| | Soybean meal | 42.4 | 52.5 | |
| | Fish meal | - | - | |
| Grower | Brewers' spent grain | 91.6 | 123.6 | 194.8 |
| | Wheat pollard | 16 | 18.7 | |
| | Rice bran | - | - | |
| | Wheat flour | - | - | |
| | Shrimp head flour | - | - | |
| | Soybean meal | 42.8 | 53.1 | |
| | Fish meal | - | - | |
| Broodstock | Brewers' spent grain | 99 | 133.6 | 196.3 |
| | Wheat pollard | 8.2 | 9.6 | |
| | Rice bran | - | - | |
| | Wheat flour | - | - | |

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As there is no specific feed for *P.hypophthalmus* available in market, many local farmers use the commercial Tilapia fish mix to feed *P.hypophthalmus*, which costs RM473 per 150 kg. In order to analyse the selling price of the proposed feed mixture from the LP model, Aizam et al. [19] have stated that the selling price of a feed mix is generally 130% of the production cost.

Table 3 shows the comparison between the selling price of commercial feed and the feed mixture obtained in this study. As there is no feed formulation for specific life stage of *P.hypophthalmus*, therefore, the feed mix average selling price of a life stage based on LP model is calculated for the mixture, with and without supplement ingredient. In contrast to the commercial feed of RM473, the average selling price per 150 kg of feed mix with and without supplement ingredient are RM349 and RM299, respectively. It is shown that the price for the feed obtained from this study is lower than the commercial feed, with or without supplement ingredient. This result has shown that the fish feed formulation derived from the LP model has been significantly reduced the selling price for about 26% to 37%.

Table 3: The Price Comparison between Optimal Feed Formulation and Commercial Feed

| *P. hypophthalmus* life stage | The selling price of *P. hypophthalmus* feed mix based on LP model per 150 kg (RM) | | Market Selling Price of Commercial feed per 150 kg (RM) |
|---|---|---|---|
| | With supplement ingredient | Without supplement ingredient | |
| Fry | 297 | 248 | 473 |
| Fingerling | 494 | 441 | |
| Grower | 301 | 253 | |
| Broodstock | 303 | 255 | |
| Average | 349 | 299 | |

Ideally, by using one single type of feed for the entire fish life stages could minimise the budget in fish culture. However, fish can reach their optimal growth when it is fed with sufficient amount of nutrient daily. This can be achieved by feeding the fish with specific feed according to the life stage. This will eventually help the fish to achieve an optimal growth as they only consume customised food at each life stage. This will indirectly increase the quality of fish harvested and the expenses invested will be offset by the expected profit gain.

## 5. CONCLUSION

This study aims to identify the nutrient requirement of *P.hypophthalmus* as there is no specific feed available in the local market. A LP model for feed formulation problem from past studies has been modified. The new model considered all four different life stages of the species in one single model. A new constraint has been added to the model which requires a supplement ingredient, cinnamon leaf powder, to be included in the feed formulation. This supplement ingredient will help in enhancing the growth of *P.hypophthalmus*. The objective of the modified linear programming model is to produce the least cost feed formulation that satisfies all minimum requirement of *P.hypophthalmus* at every life stage. After performing the computational experiments for all four life stages, the optimal cost of feed mixture with and without supplement are RM349 and RM299, respectively. This result reflects the amount of ingredient that must be included in the 150 kg of the feed mix each life stage, that will optimise the nutrients in *P.hypophthalmus* feed formulation.

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In general, the production cost of the feed formulation without supplement ingredient, cinnamon leaf powder is lower. It is undeniable that the feed mix without supplement is sufficient for the species as it supplies all nutrients requirement needed in every life stage. However, to ensure a better growth, it is advisable for the feed manufacturer to include the cinnamon leaf powder into the feed mixture. Not only this will help in enhancing the growth of the species, but also it increases the species feed efficiency and protein retention [15]. The fish farmer should also make investment by feeding fish with the mix feed with supplement, so that they will enjoy better returns.

Considering the huge gains of this study, there are rooms for improvement for future research. The new model produced the optimal solution only based on the theoretical facts, while the efficiency of the feed is not tested on real *P.hypophthalmus*. To validate the practicality of the feed, it is recommended to test the effectiveness of feed produced at each life stage. In addition, the price of the supplement ingredient, cinnamon leaf powder, is quite expensive as compared to other ingredients in the feed formulation. Therefore, it is recommended to find other alternative ingredient that has better or similar impact on the growth enhancement of the species. In addition to this, the feed formulation can also be improved by means of increasing the survival rate, diseases immunity and others.

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## CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this paper.

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