Blending of Ingredients in Aquafeed Formulation the 'Excel' Way

Tips to Farmers/Farm Managers

P. Vijayagopal
Scientist S.S., (Animal Nutrition), PNP Division
Central Marine Fisheries Research Institute, Kochi - 14.

Feed formulation is a technique to be learnt and refined by experience. To date numerous descriptions have appeared on the topic in nutrition textbooks. The exercise, even when taught over and over again, is difficult to comprehend especially by the beginners. The purpose of this contribution is to describe and share some of this author's experiences in teaching and also learning feed formulation, mainly for aquatic animal research. Previous descriptions on the subject can be had from New (1987) and Houser and Akiyama (1997) of which, New (1987) describes the subject keeping a lay man in view. The emphasis here is to describe the technique in the simplest way for the benefit of beginners in the subject of aquatic animal nutrition.

Let us start by organising the data or information required for the exercise. The checklist can be as follows:

1. List of feed ingredients available for the formulation and their proximate chemical composition and cost.
2. Specifications of the feed to be formulated in terms of protein, lipid, fibre, soluble carbohydrates (NFE or nitrogen free extract) vitamins and minerals etc., and
3. Safe levels and suitability of the levels of incorporation of certain materials for the animals to be fed (Table 4).

The primary step in formulating a feed is to organise this information in a manner in which it is convenient to the person to undertake the formulation. Readymade Tables of the aforementioned information are available. These Tables may be too huge to be referred to frequently (e.g., Appendices IV, Part A and Part B in New 1987). Hence it is advisable to construct a Table to suit one's own convenience as follows. The Table 1, shown below, includes a list of feed ingredients commonly used in and around Kochi in Kerala State and their retail cost. Contents of Tables 2 and 3 presented are also relevant in the Indian context. While these may or may not be representative, they are nevertheless useful in the absence of analytical data.

The best source of this information would be one's own analysis of the material, if he / she has access to analytical facility. If not, samples can be got analysed from approved laboratories in the government sector or private sector. Government laboratories providing this service are (1) Nutrition laboratory of PNP Division at CMFRI, Kochi (Write to The Director, Central Marine Fisheries Research Institute, P.O.Box 1603, Tatapuram (P.O.), Ernakulam, Kochi - 682 014, Kerala), (2) Animal feed quality control laboratory (AFQCL), Tamil Nadu University of Veterinary and Animal Sciences, Namakkal, Tamilnadu (Write to: Dr. D. Chandrasekaran, Prof. and Head, AFQCL, Veterinary College and Research Institute, Namakkal, Tamilnadu).

With the extensive use of computers these days, it is desirable that this information is fed into a computer in a

Table 1. List of feed ingredients commonly used in and around Cochin and their retail cost

Ingredient	*DM*[1]	*CP*[2]	*EE*[3]	*CF*[4]	*NFE*[5]	*Ash*	*AIA*[6]	*Cost (Rs./Kg.)*
Fish meal	95.16	68.50	8.49		0.61	17.56	2.71	25.00
Shrimp Waste meal	92.51	67.45	3.29		5.27	16.50	4.39	20.00
Clam meal	94.37	59.79	13.01		15.10	6.47	1.94	20.00
GNOC	94.55	43.75	8.13	5.49	30.10	7.08	2.36	9.20
Tapioca flour	87.18	2.82	0.29	1.79	80.26	2.02	0.10	7.00

[1]Dry matter, [2]Crude Protein, [3]Ether Extract, [4]Crude Fibre, [5]Nitrogen-Free Extractives and [6]Acid Insoluble Ash in %.

*Costs indicated are for dried unsalted anchovies and *Acetes* sp. respectively. It may go up to Rs.70 and Rs.120 depending upon availability.

A fair understanding of the Table containing the compositional information is a definete prerequisite before proceeding any further. The heads under which the nutrient composition is quantified can be further described as:

1. DM - Dry matter-indicates the total nutrient content excluding water.
2. CP - Crude protein-indicates the total protein content inclusive of non-protein nitrogenous substances also.
3. EE - Ether extract or crude fat-indicates the total fat content, which may include other fat soluble substances.
4. CF - Crude fibre-indicates the cellulose content or the generally indigestible carbohydrate content.
5. NFE - Nitrogen free extract or the total soluble/digestible carbohydrate, contained in this fraction.
6. Ash - indicates the total content of mineral salts.
7. AIA - Acid insoluble ash-indicates the indigestible impurities/adulterants in feed material which are mainly sand and silica.

Table 2. Proximate composition of selected feed ingredients of plant origin in India

Ingredient	DM(%)	CP(%)	EE(%)	CF(%)	NFE(%)	Ash(%)
Rice polish	87.4	14.5	17.3	7.5	n.a.	n.a.
Rice polish	90	12.2	16.0	9.0	46.8	6.0
Rice polish	91.6	11.4	15.3	11.0	41.0	12.9
Rice, broken	90	12.0	4.2	5.3	65.4	3.1
Rice bran	89.9	12.6	11.3	19.3	36.5	10.2
Rice bran	92.2	7.8	6.1	14.4	43.4	20.5
Rice bran	91.6	2.9	5.0	18.0	38.4	27.3
Rice bran	91.3	9.4	4.7	13.5	32.3	31.4
Defatted rice bran	92.8	12.1	1.3	15.2	40.4	23.8
Wheat bran	87.7	15.8	4.3	8.7	n.a.	n.a.
Wheat bran	90	13.5	2.6	12.2	58.7	3.0
Wheat bran	87	8.2	6.6	33.5	34.5	4.2
Wheat bran	90.7	12.6	7.5	11.9	54.5	4.2
Wheat, broken	91	11.5	1.9	4.0	73.4	0.2
Wheat flour	87.4	14.5	3.7	2.7	64.2	2.3
Groundnut cake	92.2	28.6	13.8	7.5	28.9	13.4
Groundnut cake	94	37.7	11.5	13.2	24.3	7.3
Groundnut cake	90	42.0	7.3	13.0	25.2	2.5
Groundnut cake	91.7	46.6	7.7	6.5	23.2	7.7
Groundnut cake	92.9	35.8	8.5	8.2	29.9	10.5
Groundnut extr.	93	48.0	2.0	11.2	29.1	2.7
Sunflower extr.	92	31.0	2.1	18.4	39.0	1.5
Sunflower extr.	89.8	30.1	2.9	24.7	25.6	6.5
Palm kernel cake	91.1	12.2	4.9	25.6	45.8	2.6
Soyabean meal	88.2	46.3	1.3	5.0	n.a	n.a
Soyabean meal	97	58.6	1.4	0.4	31.3	5.3
Soyabean meal	90	46.0	0.9	7.3	35.2	0.6
Soy asauce waste	88	13.5	8.2	5.8	55.2	5.3
Rapeseed cake	89	35.9	0.9	13.2	32.1	6.9
Salseed cake	91.4	8.2	2.9	1.7	68.4	10.2
Sesame cake	91.7	41.9	9.2	6.2	19.6	14.8
sesame cake	90	29.0	12.9	18.3	19.8	10.0
Sesame cake	90	42.7	6.9	5.7	21.8	12.9
Mustard cake	91.5	30.8	9.3	6.2	34.9	10.3
Mustard cake	90.8	23.6	9.6	6.3	40.9	10.4
Cotton seed cake	93	37.0	6.7	13.0	35.3	1.0
Cotton seed cake	91.8	42.7	1.0	12.6	27.3	8.2
Gingelly cake	91	34.0	7.8	7.9	38.2	3.1
Gingelly extr.	93	40.0	2.0	9.7	38.4	2.9
Niger extr.	93	35.0	2.0	19.0	33.5	3.5

copra cake	88	22.0	6.5	12.2	42.1	5.2
Copra cake	91.6	20.3	11.4	16.2	37.5	6.2
Copra cake	n.a.	22.0	6.0	12.0	n.a.	2.1
Tobacco seed extr.	92.3	30.6	0.3	-	47.7	13.7
Maize meal	86.5	9.5	4.0	4.0	67.5	1.5
Maize	89.6	4.6	7.8	3.5	72.7	1.0
Sorghum	90	9.0	2.8	3.0	75.1	0.1
Spirulina	91.3	50.5	1.0	2.1	26.7	11.0
Tapioca flour	88.5	3.1	2.3	2.0	78.8	2.3
Tapioca flour	92	1.8	1.3	1.8	86.9	0.2
Coffee pulp	87.7	14.0	1.2	20.8	43.5	8.2
Colocasia meal	94.2	24.6	4.5	8.2	47.0	9.9
Eichornia meal	96.7	19.5	2.3	18.3	47.3	9.3
Pistia meal	95.1	19.5	1.3	11.7	37.0	25.6
Leucaena meal	88.2	33.1	4.7	9.0	34.2	7.2
Mulberry leaf, dry	91.1	27.7	2.4	11.5	41.4	8.1
Salvinia meal	97.4	16.2	1.1	18.5	39.6	22.0

Table 3. Proximate compostion of selected feed ingredients of animal origin in India

Ingredient	*DM(%)*	*CP(%)*	*EE(%)*	*CF(%)*	*NFE(%)*	*Ash(%)*
Fish meal	91.4	64.4	7.5	0.3	-	19.2
Fish meal	90.5	53.6	5.4	3.1	7.5	20.9
Fish meal	90.8	56.1	2.5	17.8	11.9	2.5
Fish meal	85.4	37.2	2.7	22.7	16.1	6.7
Fish meal	89.4	14.4	8.7	30.0	19.8	16.5
Fish meal	86	47.8	10.3	2.6	7.0	18.3
Fish meal	90	72.0	10.0	0.5	n.a.	n.a.
Fish meal	91	50.0	7.0	1.0	29.0	4.0
Fish meal	90	45.0	8.0	1.2	29.8	6.0
Shrimp waste	90	28.0	2.7	12.5	n.a.	n.a.
Shrimp waste	91	22.5	3.6	35.3	11.0	18.6
Shrimp waste	96.4	34.2	6.7	12.2	15.4	27.9
Shrimp waste	84.4	28.3	1.1	7.1	16.3	31.6
Squilla meal	85.9	46.0	2.6	13.5	5.8	18.0
Squid meal	92	75.0	6.5	4.0	n.a.	n.a.
Clam meal	93	52.0	11.6	5.5	n.a.	n.a.
Clam meal	91.9	50.7	8.9	3.9	22.0	6.4
Silkworm pupae	92.9	43.9	25.7	4.2	3.3	15.8
Defatted silkworm pupae	91.9	68.0	2.6	1.3	12.8	7.2
Blood meal	90	65.3	0.5	n.a.	n.a.	n.a.
Blood meal	87.1	76.6	1.1	1.0	4.6	3.8
Meat meal	92	50.0	4.4	6.8	25.8	5.0
Meat meal	90	71.2	13.3	0.7	n.a.	n.a.
Liver meal	93	65.0	3.4	1.2	21.0	2.4
Earthworm meal	95	51.7	3.4	12.8	14.6	12.5

Source : Modified from Nandeesha (1993)

Table 4. Proximate compososition of the feed ingredients with approximate cost (Rs/Kg)

Ingredients	Cost (Rs./Kg.)	DM	CP	EE	CF	NFE	Ash	AIA
Fish meal	25.00	95.16	68.50	8.49	0.00	0.61	17.56	2.71
Shrimp waste meal	20.00	92.51	67.45	3.29	0.00	5.27	16.50	4.39
Clam meal	20.00	94.37	59.79	13.01	0.00	15.10	6.47	1.94
GNOC	9.20	94.55	43.75	8.13	5.49	30.10	7.08	2.36
Tapioca flr	7.00	87.18	2.82	0.29	1.79	80.26	2.02	0.10
Oil	50.00							
Cholesterol	100.00							
Lecithin	100.00							
Vitamin mix.	75.00							
Mineral mix.	30.00							

Microsoft Excel spread sheet available in the MS Office; It would them be helpful in avoiding repetitive calculations which may be required if a simple calculator is used.

Now, let us get ahead with the computation *per se*. Pearson square method used for blending two ingredients or products to attain a specific nutrient concentration until the advent of computers is not explained here. This is because of the basic drawback of this method to blend only two ingredients at a time. When more than two ingredients need to be blended multiple Pearson squares have to be used or grouping of ingredients based on criteria like 'protein rich' and 'energy rich' has to be adopted. Simple ways of doing it is described by Ali (1987), New (1987) and a detailed review is available in Church and Nipper (1984).

The method intended to be described here in detail is commonly known as the hit and trial method which is not only convenient but also clears the concept of blending of feed ingredients/products in definite proportions and the resultant changes it brings about in the blend too.

After organising the data bank to be used for the formulation, the next step is to define the requirement or composition of the feed to be made.

Taking marine shrimp as an example, let us assume the requirement in terms of nutrients for animals grown in culture ponds at a stocking density of less than 5 animals per sq.m as: protein $\geq$35%, fat not more than 7%, fibre < 3%, soluble carbohydrates (NFE) 20-40%, ash $\leq$ 15%, AIA $\leq$ 3% containing gross energy (GE) of > 400 kcal/100g and digestible energy (DE) of <300 kilocalories/100kg. GE and DE are explained later. Let us also fix that our feed mix should not cost more than Rs. 25/- per kg.

In the spread sheet, where the information regarding composition and cost, if fed into another portion of the spread sheet involving the required number of rows and columns, can be used for computation as shown in Table 4 above.

The trial to blend the ingredients available can be started by assigning the number of parts of a particular ingredient or it can be expressed as percentage of inclusion. Knowledge of the safe levels of incorporation of a particular in-

Cost of Inclusion of Ingredients at Trial Proportions : Blend A

	% of Inclusion	Inclusion out of 1	Cost [Rs./Kg]	CP	EE	CF	NFE	Ash	AIA
Fish meal	20.00	0.200	5,000	13.70	1.70	0.00	0.12	3.51	0.54
Shrimp meal	20.00	0.200	4,000	13.49	0.66	0.00	1.05	3.30	0.88
Clam meal	20.00	0.200	4.000	11.96	2.60	0.00	3.02	1.29	0.39
GNOC	20.00	0.200	1.840	8.75	1.63	1.10	6.02	1.42	0.47
Tapioca flr.	9.00	0.090	0.630	0.25	0.03	0.16	7.22	0.18	0.01
Oil	5.00	0.050	2.500		5.00				
Cholesterol	0.50	0.005	0.500						
Lecithin	0.50	0.005	0.500						
Vitamin mix.	3.00	0.030	2.250						
Mineral mix.	2.00	0.020	0.600						
Total	100.00	1.000	21,820	48.15	11.61	1.26	17.44	9.70	2.29
Cost of nutrients									
GE kcal/100g				264.83	105.65		71.50		441.99
DE kcal/100g				200.59	41.76		33.05		275.41

Cost of Inclusion of Ingredients at Trial Proportions : Blend B

	% of Inclusion	Inclusion out of 1	Cost [Rs./Kg]	CP	EE	CF	NFE	Ash	AIA
Fish meal	15.00	0.150	3,750	10.28	1.27	0.00	0.09	2.63	0.41
Shrimp meal	15.00	0.150	3,000	10.12	0.49	0.00	0.79	2.48	0.66
Clam meal	15.00	0.150	3,000	8.97	1.95	0.00	2.27	0.97	0.29
GNOC	20.00	0.200	1,840	8.75	1.63	1.10	6.02	1.42	0.47
Tapioca flr.	24.00	0.240	1,680	0.68	0.07	0.43	19.26	0.48	0.02
Oil	5.00	0.050	2,500		5.00				
Cholesterol	0.50	0.005	500						
Lecithin	0.50	0.005	500						
Vitamin mix.	3.00	0.030	2,250						
Mineral mix.	2.00	0.020	600						
Total	100.00	1.000	19,620	38.79	10.41	1.53	28.43	7.98	1.85
Coat/nutrients									
GE kcal/100g				213.33	94.77		116.56		424.66
DE kcal/100g				160.61	83.31		53.99		297.90

Cost of Inclusion of Ingredients at Trial Proportions : Blend C

	% of Inclusion	Inclusion out of 1	Cost [Rs./Kg]	CP	EE	CF	NFE	Ash	AIA
Fish meal	10.00	0.100	2,500	6.85	0.85	0.00	0.06	1.76	0.27
Shrimp meal	10.00	0.100	2,000	6.75	0.33	0.00	0.53	1.65	0.44
Clam meal	10.00	0.100	2,000	5.98	1.30	0.00	1.51	0.65	0.19
GNOC	30.00	0.300	2,760	13.13	2.44	1.65	9.03	2.12	0.71
Tapioca flr.	29.00	0.290	2,030	0.82	0.08	3.63	23.28	0.59	0.03
Oil	5.00	0.050	2,500						
Cholesterol	0.50	0.005	500						
Lecithin	0.50	0.005	500						
Vitamin mix.	3.00	0.030	2,250						
Mineral mix.	2.00	0.020	600						
Total cost/nutrients	100.00	1.000	17,640	33.52	10.00	5.28	34.40	6.76	1.64
GE kcal/100g				184.34	91.02		141.05		416.42
DE kcal/100g				136.17	80.02		61.87		278.06
Cholesterol	100.000								

gredient, cost, gelling properties, pelletability, bulk density etc., aids in assigning the number of parts of a particular ingredient. The start can be with assigning 20 parts of fish meal, 20 parts of shrimp meal, 20 parts of clam meal, 20 parts of GNOC and 5 parts of oil which totals to 85 parts per 100. These values are entered in the Excel spread sheet by taking 100% as 1. Hence, part per 100 is entered as a decimal value. Thus, 20 part per 100 = 0.2, 5 parts per 100 = 0.05, 3 parts per 100 = 0.03 and 2 parts per 100 = 0.02 and 0.5 parts per 100 = 0.005. Out of the remaining 15 parts, 3 parts of mineral mixture and 2 parts of vitamin mixture may be assigned. Since the dietary essentiality of cholesterol and phospholipids especially lecithin is proven in marine shrimps they may be provided at levels of 0.5% each making the total mix 91 parts per 100. The remaining nine parts can be either filled up with inert filler, filler with binder or an energy source like tapioca flour.

Given hereunder is the way to examine the nutrient profile (in %) of the mix by finding out the contribution of 20% fishmeal to the formulated feed as follows:

Similarly gross energy (GE) is the quality of the feed, which indicates the amount of heat, and this means energy, liberated when the material is burnt completely and digestible energy (DE) is that

portion of the energy available to the animal to which it is fed. Technically it is the GE energy lost as faeces energy. Standard values are in use for converting protein, fat and carbohydrate content. The values recommended by aquaculture coordination and development programme (ADCP, 1983) are used here which are as follows:

In the Excel spread sheet the formulae may be entered in the cell right below CP as = A1*0.2, where A1 is the cell number which contains the % CP of fishmeal. If one is working with a calculator and a work sheet these values have to be calculated as shown above and entered in the respective cells. However, in an Excel worksheet this formula, if copied using the + sign appearing on the right hand bottom corner of the cell from which we intend to copy the formula, these calculations can be completed in no time. Similarly, for all ingredients the respective formulae may be copied and the work sheet may be filled.

The total GE and DE content of the blend is calculated by multiplying the total CP, EE and NFE contents with these values. That is, total GE form protein in the first formulation will be 48.15 x 5.5 + 11.61 x 9.1 + 71.50 x 4.5 = 441.99. Similar calculations with appropriate energy values for fat and carbohydrate (NFE) given above, gives us the total GE and DE values of the blend. Care should be taken to enter multiplication formulae which begin with an = sign followed by the cell to be multiplied followed by the and then the energy value.

The last step is to total the individual nutrient components in the bottom row for which the formula is = sum (cell No.: cell No.) where the first cell number is the cell from which the totalling should start and the second cell number is the cell from which the totalling should end. Thus, one would get the final composition and cost of the feed mix, which may or may not comply with the requirements as had been defined.

After completion of this, one has to have at hand a base form, to work upon, through the innumerable permutations and combinations to achieve the required nutrient specifications and cost. If a calculator and work sheet are the tools available several worksheets have to be used to manipulate the computations. In the Excel worksheet, once a formulation is made, just by altering i.e., increasing or decreasing the part/100 figures all the corresponding figures change automatically. If several blends have to be made by modifying the inclusion rates, Tables containing nutritional and cost information of the first blend can be retained as it is and a copy of the same can be used right below as shown in Table 4. To copy the information in an Excel spread sheet containing formulae 'paste link' button has to be clicked after selecting the area to be copied from the drop-down 'edit menu'. Simple copy and paste menu if used, a copy of the data will show erroneous calculated values because destination cells change while copying.

Crude protein (CP) available from 20% fish meal (FM)	**= CP in FM x 20/100**
	= 68.5 x 20/100
	= 13.70
Ether extract (EE) or crude fat available from FM	= EE in FM x 20/100
	= 8.49 x 20/100
	= 1.70
Crude fiber (CF) available from FM	= 0
Nitrogen free extract (NFE) or soluble carbohydrates available from FM	= NFE in FM x 20/100
	= 0.61 x 20/100
	= 0.12
Ash (total minerals) available from FM	= Ash in FM x 20/100
	= 17.56 x 20/100
	= 3.51
Acid insoluble ash (AIA) or inert material contributed by FM	= AIA in FM x 20/100
	= 2.71 x 20/100
	= 0.54

Nutrient	*Gross energy (GE) kcal/g*	*Digestible energy (DE) kcal/g*	
Protein	5.5	Animal protein	4.25
		Vegetable protein	3.8
Fat	9.1		8.0
Carbohydrate	4.1	Animal carbohydrate	3.0
		Vegetable carbohydrate	2.0

In conclusion, a brief description of using Excel, which is used in feed formulation here, is presented here for beginners. Once Excel is open, we can see a grid of rows and columns. A number labels each row, and a letter of the alphabet labels each column. The limit within a worksheet is 256 columns and 16,384 rows. It may be noted that there are tabs at the bottom of the screen to indicate the sheet tabs (Sheet 1, Sheet 2 and so on); the programme will open with 16 worksheets available within the overall workbook.

The programme opens with the highlight on cell A1 (Column A, Row 1) in the upper right-hand corner of the sheet. As a means of learning these, some basic functions of the programme are to be used.

Number 10 need be entered into cell A1 and the number 20 into cell B1. The cursor is be moved back to cell A1, the shift key may be held down, and the arrow keys are to be used to move the cursor over to cell B1. Both the cells will now be highlighted. From the drop-down edit menu, 'Copy' has to be clicked on. Arrow keys or the mouse has to be moved to cell A2. The Edit menu is to be clicked again, then ' Paste' is to be clicked. The contents of cells A1 and B1 have now been copied to cells A2 and B2.

An alternative method of copying is to use the mouse and a built-in copying feature of Excel. First, the Delete key is to be used to clear the contents of cells A2 and B2. Then cells A1 and B1 are to be highlighted as was done earlier. Now,

the black square may be noted in the lower right-hand corner of the highlight area. When the mouse cursor is placed directly over this back square, it will change to a thick white cross to narrow back cross. Then the mouse button has to be held down and the contents of cells A1 and B1 will be copied to cells A2 and B2. Another convenient feature of a spreadsheet is that it allows the user to input formulae into cells. Formulae can use data in various cells to perform calculations, and formulae can be easily copied to other cells using copying methods described above. To illustrate this point, the contents of cells A1 and B2 may be added, making sure these cells still contain 10 and 20, respectively. Arrow keys may be used or the mouse may be used to move to cell C1. In Excel, formulae always start with '=A1 + B1' into cell C1. Once this formula is applied and, over the cursor (or the Enter key may be hit), Excel will calculate the formula. If desired, the formula can be copied down the column as described in the previous example on copying.

In addition to copying formulae down a column, they can be copied across a row. It may however be noted that, when formula are copied across a row the cell references change. To illustrate this, the formulae in cell C1 to cell D1 may be copied. Now the cell pointer and the formula bar are to be looked at, which are located just above the column headings. The formula in cell D1 shown on the formula bar is '=B1 + C1'; hence, the cell reference has shifted one column to the right. In situations where it is desired that a formula refers to a specific cell or a range of cells, the formula can be written with the '$' modifier, which points to a specific cell, row, or column depending on how it is used. For example, if it is wanted to use the value in cell A1 as the divisor for a series of numbers in column B, what is to be done is to input the equation into cell C1 as '=B1/$A $1'. Then when this equation is copied down column C, every value in column B would be divided by the value in cell A1. With this brief introduction, and with the use of Help menu in the programme or with the assistance of someone well versed in Excel spread sheet operations a construction of a diet formulation spread sheet should be easy.

Linear programming software is inbuilt in Excel and can be accessed though Solver in the Tools menu. This is very popular among professional animal nutritionists. *www. incomemax. com* is a site where feed-mixing can be done online, of course for a fee.

Disclaimer : Neither this author nor CMFRI either endorses or implies criticism of the products/services mentioned in this article.

Suggested further reading : Ali, S.A. (1987) Feed formulation methods. In CMFRI Special Publication No.8. Manual of Research methods for Fish and Shellfish Nutrition pp. 95-98.

Church, D.C. and Nipper, W.A. (1984) Ration formulation. Pages 195-227 In D.C. Church editor, Liverstock feeds and feeding, 2 edition O.B. Brooks Inc., Conrnvalis, Oregon, USA.

Houser, R.H. and Akiyama, D.M. (1997) Feed formulation principles. In Crustacean Nutrition, Advances in World Aquaculture, Vol.6 Eds. D' Abramo, L.R.,Conklin, D.E. and Akiyama, D.M. World Aquaculture Society, pp.493-519.

NANDEESHA, M.C. 1993. Aquafeeds and feeding strategies in India, p. 213-254. In M.B. New, A.G.J. Tacon and I. Csavas (eds.) Farm-made aquafeeds. Proceedings of the FAO/ AADCP Regional Expert Consulation on Farm-Made Aquafeeds, 14-18 December 1992, Bangkok, Thailand. FAO-RAPA/ AADCP, Bangkok, Thailand, 434 p.

New, M.B. (1987) Feed and feeding of fish and Shrimp - Manual on the preparation and presentation of compounded feeds for shrimp and fish in aquaculture. FAO/ADCP/87/26.