National Training Workshop on

Seaweed Farming and Processing for Food

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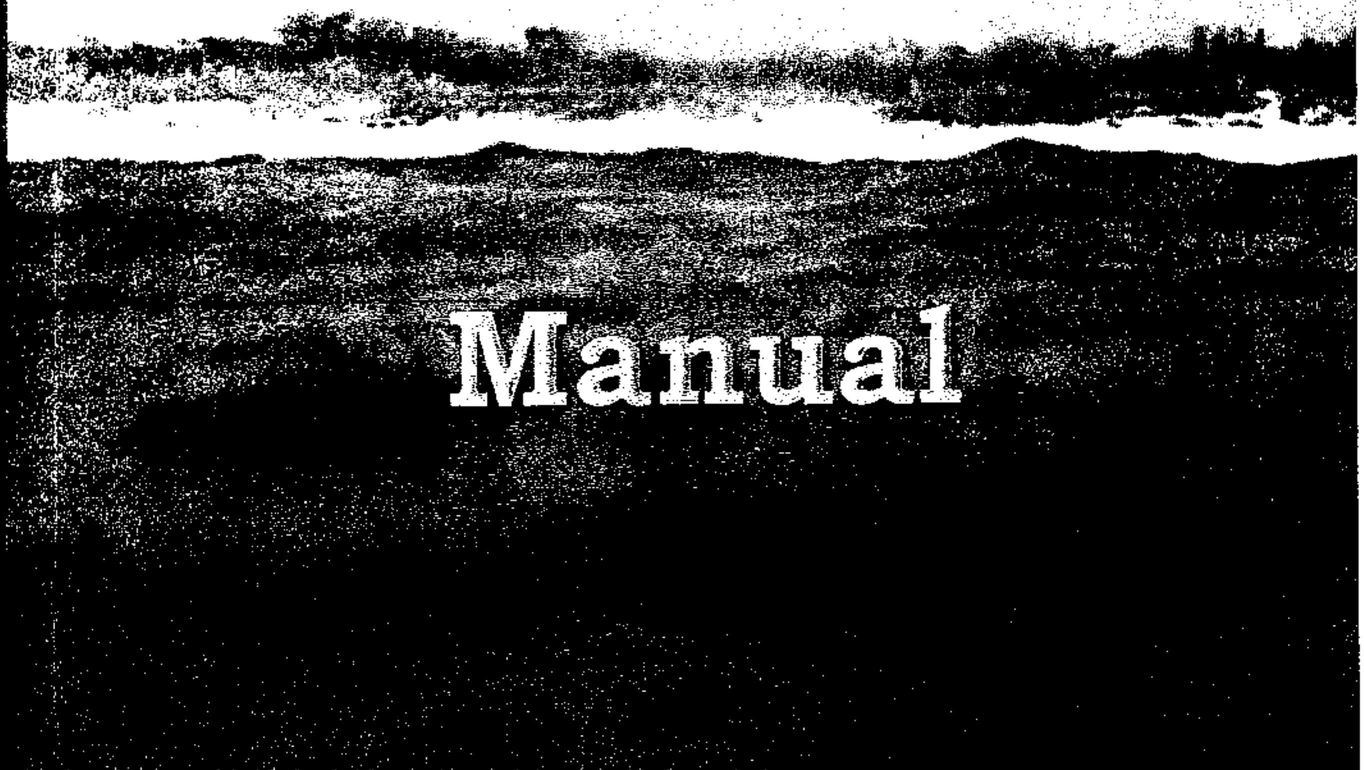

Manual

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Animal feed from seaweeds

P. Kaladharan
Central Marine Fisheries Research Institute
Cochin - 682 018, Kerala

Introduction

Rural India today is not fodder-secure and the grim reality is that food security in this country is impossible without fodder security. We lack policies on how to feed nearly 500 million animals. Our agriculture production is stagnating and our farmers are shifting to crops that do not yield fodder resulting into a crisis. Shrinkage of cultivable land due to urbanization and shortage of water, limit the possibility of producing more feed and fodder to livestock from land.

As per 1995-96 data (FAO 1996), availability of oil cake was only 20.74 million tons (mt) as against the annual requirement of 496.58 mt. Similarly, the availability of green and dry fodder was 300 mt and 310 mt respectively as against the requirement of 2037 mt and 722 mt respectively. Therefore, we must continually strive to keep pace with desired production level of our livestock. Sea remains untapped and the seaweed resources have got immense potential to fill the gap in India. Seaweed is one of the such unconventional ingredients which is available in large quantities and needs to be taken on priority basis for its optimum utilization in animal ration to meet out the requirements of feeds and fodder. Seaweeds were used as animal feed as early as first century BC by the Greeks. Seaweed has been used by farmers living near the sea in Europe. In Norway *Ascophyllum* is used as pig meal. *Rhodymenia palmata*, a red seaweed is called cow weed in Britain and horse weed in Norway. Dried and processed seaweeds have been used as animal feed in Europe and North America.

Nutritive values of some seaweeds

Seaweeds	Calories (Cal/g ash free dw)	Organic C (% d w)	Ar	Cu (ppm/d w)	Zn	Mn
Sargassum tenerrimum	3515	29	10.4	20	36	302
Padina tetrastromatica	4406	23	12.6	8.7	20	456
Hypnea musciformis	7827	29	2.5	8.6	51	193
Ulva fasciata	2864	70	2.8	6.8	17.8	203
Dictyota dumosa	4490	79	3.5	8.0	16	125
Gracilaria corticata	5493	75	4.0	11	15.5	211
Caulerpa sertularioides	2850	65	2.9	12.6	6.4	115

Source: Jagtap and Untawale, 1984.

Feed trials

Seaweeds are rich in protein (20-25%), carbohydrate (50-70%), vitamins, minerals and certain drugs. When used in animal feed, cows produced more milk, chicken eggs became better pigmented and horses and pets became healthier (White and Keleshian, 1994). Presence of tocopherol and vitamin-E in seaweeds increased the fertility rate and birth rate of animals when used as fodder. Both milk production and fat content have been found to increase by using seaweed as part of the diet. Feed supplemented with *Gracilaria* and /or *Spirulina* to layer chicks (white leghorn) increased the number of eggs, size and colour of yolk (Chaturvedi *et al.* 1985). Dave *et al* (1977) assessed the possibility of seaweeds being used as supplementary animal feed and they reviewed the feeding trials of farm animals with seaweeds conducted in Japan, Germany, UK and Norway. Cattle grazed on *Laminaria* sp. based diet have better natural resistance to diseases such as foot and mouth. In USA, when hens were fed with 1.25% seaweed added to their normal ration, the proportion of thin celled-eggs were reduced from 3-19% and when after 3 months the seaweeds addition to the diet was discontinued, the proportion of thin celled-eggs again increased.

The biochemical composition (total protein, amino acids, lipid and fatty acids) of the four species of algae revealed that *Ulva lactuca*, *Enteromorpha compressa* (Chlorophyta), *Padina pavonica* (Phaeophyta) and *Luurencia obtusa* (Rhodophyta) are potential sources of dietary protein and lipid for fish. Protein content (% dry weight) ranged from 13.6% in *E. compressa* to 24.5% in *L.obtusa*. The lipid content (% dry weight), by contrast, ranged from 4.6% in *E.compressa* to 6.2% in *L. obtusa*. All essential amino acids except methionine and cystine in *L. obtusa*, proline in *P.pavonica*, proline and cystine in *U.laçtuca* were present in relatively high levels. Polyunsaturated fatty acids represented 50.1 to 66.3% of the total fatty acids, whereas saturated fatty acids accounted for 15.0 to 30.1% of the total fatty acids (Wahbeh, 1997).

Amino acid profile of six species of seaweeds (g/100 g dry wt)

Sargassum wightii	- 10.58
Ulva lactuca	- 11.73
Kappaphycus alvarezii	- 5.21
Hypnea musciformis	- 19.59
Gracilaria corticata	- 14.80
Acanthophora spicifera	- 8.99

Source: Vinoj kumar and Kaladharn, personal communication

In a study aimed to evaluate the inclusion of three seaweeds *Gracilaria bursapastoris* (GB), *Ulva rigida* (UR) and *Gracilaria cornea* (GC) as dietary ingredients on the performance, nutrient utilisation and body composition of European sea bass (*Dicentrarchus labrax*) juveniles, six experimental diets were formulated to replace 5% (GP-5, UR-5, and GC-5 Diets) and 10% (GP-10, UR-10 and GC- 10 Diets) fish protein hydrolysate (CPSP) by each of the three seaweeds. The results obtained in this study suggests that the inclusion of *G.bursapastoris* (GP) and *U. rigida* (UR) up to 10% can be considered as very interesting ingredients in diets for sea bass juveniles. as no negative consequences on growth performance, nutrient utilization or body composition were observed. On the other hand, the inclusion of *G. cornea* (GC) should be limited to 5% of the diet (Valente *et al.*, 2006).

A study undertaken to evaluate the nutritional role of polyunsaturated fatty acids (PUFA) in five species of dietary macroalgae *(Alaria esculenta, Laminaria digitata, Laminaria saccharina, Palmaria palmata* and *Ulva lactuca)* for the abalone *Haliotis tuberculata* and *Haliotis discushannai,* it was found that based on specific growth rates the dietary values of these macroalgae can be listed in a decreasing order as follows: *P. palmata, A.esculenta, U. lactuca, L. digitata* and *L. saccharina* for *H. tuberculata* and *A. esculenta, P.palmata, L. digitata, L. saccharina* and *U. lactuca* for *H. discushannai* (Mai *et al.*,1996). Their fatty acid analysis revealed that Crs and Czo PUFA, such as 18:4n-3, 18:3n-3,20:4n- 6 and 20:5n-3, were dominant in the brown algae *A.esculenta, L. digitata* and *L.saccharina.* The red alga *P. pulmuta,* was characterised by the highest proportion of 20:5n-3 among the selected algae. In the green alga *U. luctuca,* however, the dominant PUFA were CL6 and C,a fatty acids, while Cza fatty acids were minimal. All the selected algae consistently contained very low levels of C, fatty acids. Statistical analyses demonstrated that (a) 20:5n-3 played a prominent role in the nutrition of both abalone species; (b) 18:3n-3 as well as long-chained PUFA also contributed to the faster growth of *H. tuberculata* and *H.discus hannai* respectively.

Lipid composition of abalone was examined over a one-year interval by Nelson *et al.* (2002). A feeding trial was designed by them to cover a full reproductive cycle in young adult green abalone *Haliotis fulgens*, consisting of five diet treatments: the macrophytic algal phaeophyte *Egregia menziesii,* rhodophyte *Chondracanthus canaliculatus*, chlorophyte *Ulva lobata*, a composite of the three algae and a starvation control. The lipid class, fatty acid, sterol and 1-*O*-alkyl glyceryl ether profiles were determined for foot, hepatopancreasygonad tissues and larvae. The major fatty acids were 16:0, 18:0, 18:1(*n*-7)c, 18:1(*n*- 9)c, 20:4(*n*-6), 20:5 (*n*-3) and 22:5(*n*-3), as well as 14:0 for abalone fed brown and red algae. 4,8,12-Trimethyltridecanoic acid, derived from algae, was detected for the first time in *H. fulgens* (hepatopancreas complex, 1.2–13.9%; larvae, 0.5% of total fatty acids). Diacylglyceryl ethers were present in larvae (0.6% of total lipid). The major 1-*O*-alkyl glycerols were 16:0, 16:1 and 18:0. Additionally, 18:1(*n*-9) was a major component in hepatopancreasygonad and larvae. The major sterol was cholesterol (96–100% of total sterols). Highest growth rates were linked to temperature and occurred in abalone fed the phaeophyte *E. menziesii* (43 mmØday, 56 mgØday yearly mean), an alga containing the -1-1 highest levels of C polyunsaturated fatty acids and the highest ratio of 20:4(*n*-6) to 20:5(*n*-3). This study provides 20 evidence of the influence of diet and temperature on seasonal changes in abalone lipid profiles, where diet is most strongly related to body mass and temperature to shell length.

In another study, a 60-day feeding trial was conducted to assess the suitability of three red algae *Hynea spinella, Hynea musciformis and Gracilaria cornea*, as potential feed for the culture of juvenile abalone *Haliotis tuberculata coccinea* R.Protein and carbohydrate contents were highest in *H. musciformis* and lowest in *G. cornea*. Survival rates of juvenile abalone were very good, regardless of the algae fed. This study suggested the good potential of any of the three red seaweeds tested and their nutritional composition being similar to other macroalgae used as feed for abalone and matching the abalone protein and lipid requirements (Viera *et al.,* 2005).

In shrimp diets, two seaweed meals were tested as binders. In the first study, *Kappuphycus alvarezii* or *Gracilaria heteroclada* in dry ground form were added to an isonitrogenous diet at 3, 5, 7 or 10%. The basal diet had 5% corn starch and 5% wheat flour as binders and served as the control diet. A second study used the seaweed meals at 5, 10 or 15% plus 5% wheat flour and a control diet containing 15% wheat flour (no seaweed meal). These two sets of diets were fed to juvenile tiger shrimp *Penaeus monodon* to assess the acceptability of the seaweed meals in terms of shrimp growth and survival. Diets with 5% and 10% *K. alvarezii* or *G. heteroclada* had the best FCR. Survival was highest among shrimp fed 5% *G. heteroclada* but was not significantly different from those of the control, 10% *G. heteroclada* and 10% *K.alvarezii* groups. Thus, as a supplement for wheat flour, up to 5% *K. alvarezii* or 10% *G. heteroclada* meal could be used with no adverse effect on growth (Penaflorida and Golez, 1996).

A fibre-free diet supplemented with cellulose, Nori or Wakame as the principal source of dietary fibre was fed to rats for 12 days and the cecal bacterial activities (_-glucuronidase, _-glucosidase, azoreductase, nitroreductase and nitrate reductase) were measured. The intake of seaweeds did not affect body weight gain nor food intake. However, algae in the diet was associated with a significant increase on cecal, fresh stool and dry stool weight. All bacterial enzyme activities were lower in the two seaweed groups than the cellulose fed group with exception of the _-glucosidase which was significantly lower in rats fed Wakame. Adaptation to diets containing Nori or Wakame was associated with changes in microbial activity that involved a decrease on reductive and hydrolytic enzymatic activities implicated in the conversion of procarcinogens into carcinogens (Urbano and Gani, 2002).

The rare breed of primitive sheep on North Ronaldsay, Orkney (Scotland) survives under extreme conditions on the beach shore of North Ronaldsay with seaweed as virtually their sole feed source.

In a study the qualitative and quantitative seaweed diet of the sheep was evaluated. The feral sheep were observed eating a broad variety of seaweed species but due to apparent preference and availability, mainly brown kelps (*Laminaria digitata* and *Laminaria hyperborea*) were consumed during this summer study. A feeding study was completed with 12 North Ronaldsay sheep for 5 days. In order to reproduce natural conditions as close as possible each sheep was fed ad libitum with a *L. digitata* and *L. hyberborea* mixture in a pen on the beach. To establish if the seaweed intake was dependent on an adapted micro-flora in the digestive system, six of the North Ronaldsay sheep were adapted to feeding on grass for 5 months before the start of the trial, and the remaining six sheep were kept on their normal seaweed diet. In view of the unusual diet and the potential for using seaweeds as feeds for ruminants elsewhere, dry matter degradation (DMD, 71.7%, at 48 h) and organic matter digestibility (OMD, 79.6%) were measured with *L. digitata* and *L. hyperborea* in domestic sheep that had not eaten seaweed before. Measurements were carried out on a mixture of the two brown algae to reproduce the situation of the North Ronaldsay sheep. The high values of digestibility measured and the fact that North Ronaldsay sheep apparently are able to meet their energy needs from their seaweed diet, suggests that the use of these seaweeds as an alternative feed source for ruminants may be possible under some circumstances (Hansen *et. al.*, 2003).

Experiments using 3500 sheep showed that an addition of 35 gm per day of seaweed meal gave a 3.3% increase in winter wool which was increased a further 17% even if the sheep had no mineral supplement In the case of cows, use of seaweed meal increased butter fat content by 6.8% over a seven year experimental period and also reduced the incidence of mastitis. Seaweeds are known to have essential aminoacids ratio which is considered optimum for human food. Studies indicate that digestibility of *Macrocystis pyrifera* and *Sargassum* spp by bovine cattle is 85% and 55% respectively. Seaweed treated pasture forages increased immunity in pigs and chicks (Beaz *et al*, 1988).

Commercial feeds

Tasco-14 - a feed derived from *Ascophyllum nodosum* benefits overall immunity of cattle. Supplementing *Tasco-14* at 2% of the diet during 2 week period reduced the occurrence of pathogenic *E.coli* by more than 80%, thereby increases the shelf life of the beef.

Seaweed meal produced by *Maxicarp* is known to

- increase milk production and in some cases butterfat content
- improve fertility, possibly related to the level of tocopherol and lower incidence of mastitis
- support an active intestinal flora in the animal's gut. Mannitol and other chelating agents also improve nutrient utilization.

Merits of seaweed as animal feed

Seaweed diet	Effect on Animals	Reference
Seaweed supplemented forage.	Improves immune function in pigs and poultry.	US Patent No 6338856
	Imparts resistance to PRRS diseased pigs.	do
	Mitigate the stress of weaning in lactating mares.	do
Seaweed supplemented feed.	More milk in cows. Chicken eggs better pigmented. Horses & Pets healthier.	White & Kaleshian 1994
Gracilaria/ Spirulina supplemented feed.	No. of eggs more in W.L layers. Size and yolk colour improved.	Chathurvedi *et al* 1985
Seaweed treated pasture forages.	Increased immunity in Pigs and Chicken.	Allen & Pond, 2002
Fucoxanthin pigments of Seaweeds.	Improves yolk colour.	Jensen, 1966
Iodine of seaweeds.	Enhance butter & fat in milk.	do
Sargassum supplemented feed.	50 % reduction in salmonella in chicks.	Kim, 1972
Fortified seaweed meal with calcium posphate (3%)	6 % increased milk production in lactating cows	Vebb & Jensen, 1966

Acadian- a kelp meal marketed by Morgrove Holsteins Limited proved to

- boost the immune system by strengthening the glandular systems
- improve conception rates and increase the number of normal healthy births
- promote regular heat cycles
- increase sperm counts, motility and durability
- stimulate appetite and improve digestive capacity
- increase production and performance levels
- produce healthy coats
- maximise overall animal health and
- help to detoxify the body after exposure to moldy feeds (mold inhibitor).

Formulation of seaweed supplemented animal feed

Shrimp/fish feed

The feed ingredients and other additives like oil, vitamin premix and mineral mix are to be weighed as per the standard feed formulation given in the Table below.

Percentage composition of fish/shrimp feed

Ingredient	Feed			
	E1	*E2*	*E3*	*Control*
Fish meal	25	20	15	30
Soyabean meal	15	15	15	15
Shrimp meal	20	20	20	20
Gracilaria meal	15	20	25	0
Tapioca powder	12	12	12	12
Vegetable oil	8	8	8	8
Cod liver oil	4	4	4	4
Chromic oxide	1	1	1	1
Gelatin	0	0	0	5
Vitamin mix(VM)	2.5	2.5	2.5	2.5
Mineral mix (MM)	2.5	2.5	2.5	2.5

VM (mg/100gdrydiet)- Para amino benzoic acid5.55;Inositol22.06; Nicotinic acid22.21; calcium pantothenate 33.31; Pyridoxine HCl 6.66; Tocopherol 11.10; Calciferol 6.66; Sodium ascorbate 110.3

MM (g/Kg dry diet)- K_2PO_4- 1.008; Na_2HPO_4- 2.167; CaH_2PO_4 $2H_20$ – 2.617; $CaCO_3$- 0.978; Calcium lactate- 1.663; KCl-0.282; $MgSO_4$ $7H_2O$ -0.048; $MnSO_4 6H_2O$-0.0108; $CuCl_2$- 0.0015; KI-0.0023; $CoCl_2$ $6H_2O$- 0.0141

Fishmeal, soyabean meal, seaweed meal, tapioca powder and the like are weighed, cooked in a pressure cooker after thorough mixing. To the cooked mixture, oils, vitamin mix and mineral mix are added and homogenized to obtain dough. The dough is palletised by passing through an extruder. The feed pellets are dried in sun and then in oven at 60±1°C for 12 hours.

Poultry/ pig feed

Treat clean seaweed with 1% acetic acid (2:1) for 2 days. Decant the seaweed extract and mix with rice bran to form a dough. Pelletize the dough through the extruder and then dry the pellets for storage.

Pulverize dry seaweeds and sieve through suitable mesh to obtain seaweed powder. Mix this powder with rice bran or any cereal powder.

Cattle feed

Treat hays or forage grasses with seaweed extract (brown seaweeds). Dried in sun and can be fed to cattle.

Holothurian feed

Mix together fine clay from coastal sediment with fine seaweed powder in the ratio of 75:25 (w/w). Pelletised and dried.

Conclusion

India is endowed with 6000 km coastline and bestowed with more than 0.2 mt/year wet harvestable biomass of seaweeds belonging to 700 species. Of these, nearly 60 species to the tune of 30 % are economically important for their polysaccharides. Others amounting to 70 % of the biomass are underutilised. These underutilised or unutilised seaweed resources can be used as fodder or feed for animals either raw or as processed. Species of *Enteromorpha, Ulva, sargassum,Chnoospora, Acanthophora, Hypnea, Gracilaria, Chaetomorpha* and *Caulerpa* can be best tried as fodder. These seaweeds grow luxuriantly in the intertidal and subtidal waters along our peninsular coastline and the Andaman-Nicobar and Laccadive archipelago.

When they are exploited for the purpose of fodder, efforts must be started with immediate effect to augment their production through mariculture means.

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