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SUMMARY – Mediterranean fish farming is focused on the intensive production of carnivorous fishes (i.e. trout, seabass and seabream), and formulated feed is the main production cost. Due to this growth in production the Mediterranean aquafeed market has grown by 58% in the 1995-2000 period. Parallel to these increases in production of aquafeed for marine fish there has been a substantial improvement in feed efficiency. Given the special environment of this developing business, aquafeed companies play an important role in the sector, not only by supplying fish feeds, but also by providing assistance through a wide range of services that are very difficult to find by other means. The challenges for the aquafeed industry in the Mediterranean are linked to the aquaculture sector itself and involve all issues threatening future development, among them the use of raw materials, the re-organization of aquafeed companies, and the adaptation to consumer and social demands.

Keywords: Aquafeeds, aquaculture, Mediterranean.

RESUME – *"Production d'aliments pour aquaculture dans la région méditerranéenne". L'aquaculture méditerranéenne est axée sur la production intensive de poissons carnivores (c'est-à-dire truite, bar et daurade) où l'aliment formulé est le principal coût de production. En raison de cette expansion de la production, le marché méditerranéen d'aliments pour aquaculture s'est accru de 58% sur la période 1995-2000. Parallèlement à cette augmentation de la production d'aliment pour poissons marins il y a eu une amélioration substantielle de l'efficacité alimentaire. Etant donné l'environnement spécial de cette activité en expansion, les firmes d'aliments aquacoles jouent un rôle important dans le secteur, non seulement en approvisionnant en aliment poisson, mais aussi en apportant une assistance pour une vaste gamme de services, très difficiles à obtenir d'une autre façon. Les défis que doit relever l'industrie des aliments aquacoles en Méditerranée sont liés au secteur de l'aquaculture en soi et impliquent toutes les questions qui menacent son développement futur, parmi elles l'utilisation de matières premières, la réorganisation des firmes d'aliments aquacoles, et l'adaptation à la demande des consommateurs et aux exigences sociales.*

Mots-clés : *Aliments pour aquaculture, aquaculture, Méditerranée.*

Mediterranean aquaculture: Current production status

Mediterranean aquaculture production has grown steadily over the years. Looking closely at the annual growth rate it can be observed that total aquaculture production in the region totalled approximately 1,350,000 tonnes in 2001 (Table 1), which represented an increase of 81.8% from 1992 to 2001 and an annual growth rate of 7.1% during this period.

Table 1. Aquaculture production in the main species groups in the Mediterranean (tonnes) (Source: FAO-FIDI, 2003)

	1992	1995	1998	2001	Growth '92-'01	Annual growth rate
Molluscs	461,828	566,595	633,560	626,080	35.6	3.7
Freshwater fishes	122,700	104,406	156,297	293,449	139.2	12.0
Marine fishes	33,701	68,408	136,835	253,137	651.1	25.7
Diadromous fishes	119,045	146,746	171,306	173,812	46.0	4.4
Aquatic plants	5,052	5,100	3,060	3,013	-40.4	-4.5
Crustaceans	240	273	560	286	19.2	8.9
Total	742,566	891,528	1,101,618	1,349,777	81.8	7.1

Although Mediterranean aquaculture used to focus more on mollusc production (62% in 1992), the share of fish production is progressing constantly (from 37% in 1992 to 53% in 2001), similarly to the world aquaculture trend.

The marine fish species group (seabream, seabass, mullets, etc.) has shown the fastest growth rate, increasing from 33,701 tonnes in 1992 to 253,137 tonnes in 2001, corresponding to an annual growth rate of 25.7% over this period. Freshwater fish (mainly tilapia and carp) also experienced a significant growth rate over this same period (from 122,700 tonnes to 293,449 tonnes, corresponding to a 12% annual growth). Diadromous fish species (trout at the top of the list), however, had an annual increase of only 4.4% during the same period (from 119,045 tonnes in 1992 to 173,812 tonnes in 2001).

Besides finfish, the overall mollusc production (mainly mussels, oysters and clams) has developed less significantly with an annual growth of 3.7%, moving from 461,828 tonnes in 1992 to 626,080 tonnes in 2001. The output of crustaceans and seaweeds is still limited, *Gracilaria* being the main species of seaweed cultured in the region with over 3000 tonnes harvested in 2001. With regard to crustaceans, the 2001 production of various shrimp species and the red swamp crawfish (*Procambarus clarkii*), amounted only to 260 and 26 tonnes, respectively.

In the Mediterranean countries aquaculture production is dominated by six countries: Egypt, Spain, France, Italy, Greece and Turkey (Table 2), which jointly supply 96% of the total production in the region. Whereas in Spain, France and Italy the production is mainly based on molluscs (mussels, oysters, and clams), in Egypt, production is based on the semi-intensive freshwater (mainly tilapia and carp) and marine finfish species (mullet). Greece and Turkey, among others, concentrate mainly on the intensive production of selected finfish (seabream, seabass and trout). The average growth rate in these countries over the last decade has been impressive, with 24.6% in Egypt, 26.4% in Turkey and 20% in Greece.

Table 2. Mediterranean fish production and aquafeed market of main species intensively cultured

Species	1995			2000		
	Fish prod. (t)†	FCR††	Feed market (t)	Fish prod. (t)	FCR	Feed market (t)
Trout	137,988	1.3	179,384	165,866	1.0	165,866
Seabream	24,446	2.4	58,670	81,905	2.2	180,191
Seabass	22,218	2.7	59,989	59,824	2.3	137,595
Turbot	2,951	1.2	3,541	4681	1.1	5,149
Eel	4,159	1.5	6,239	3598	1.5	5,397
Sea trout	2,287	1.5	3,431	2150	1.5	3,225
Atlantic salmon	2,250	1.4	3,150	436	1.3	569
Total	196,299		314,404	318,345		497,990

†Source: FAO-FIDI, 2003.
††FCR are feed conversion ratios estimations compiled by authors from the aquafeed industry.

Mediterranean aquafeed markets

As regards aquafeeds, the Mediterranean market is focused on the production of formulated feeds for intensively produced carnivorous fishes, mainly represented by trout, seabass and seabream (Table 2). Other important fish species, albeit with a much lower production, are turbot, eel, sea trout and salmon.

Due to the growth in production of marine fish species, the Mediterranean Aquafeed market has significantly grown from an estimated production of 315,000 t in 1995 to 500,000 t in 2001, a 58% increase. It is highlighted that parallel to these increases in production of aquafeed for marine fish there has been a substantial improvement in feed efficiency. Thus, whereas the average FCR (feed

conversion ratio) for seabass cultured in Spain in cages was estimated to be 2.7 in 1995, nowadays it is about 2.3 or less.

This growth has had a significant effect on the feed market. Whereas in 1995 trout feed made up 57% of the total estimated market, in 2001 it reached only 33%. Feeds for marine fish, fundamentally seabream and seabass, accounted for 64% in 2001, now holding the greatest share of the market.

Practically the whole of the aquafeed market (93% in 2001) is concentrated in only 5 countries: Spain, Greece, France, Italy and Turkey (Fig. 1). The great development of intensive fish farming in recent years is noteworthy in countries such as Greece and Turkey, meaning an important change in the distribution of the market. In 1995 it was Italy and France that held more than 50% of the market share, however in 2001 their share of the market was less than 30% whilst Greece shifted from a 16 % share in 1995 to 30% in 2001. This trend is followed by Turkey with a growing aquafeed market share and, to a lesser extent, Spain. Tables 3 to 6 include the fish production data and the fish feed market estimations in the different Mediterranean countries.

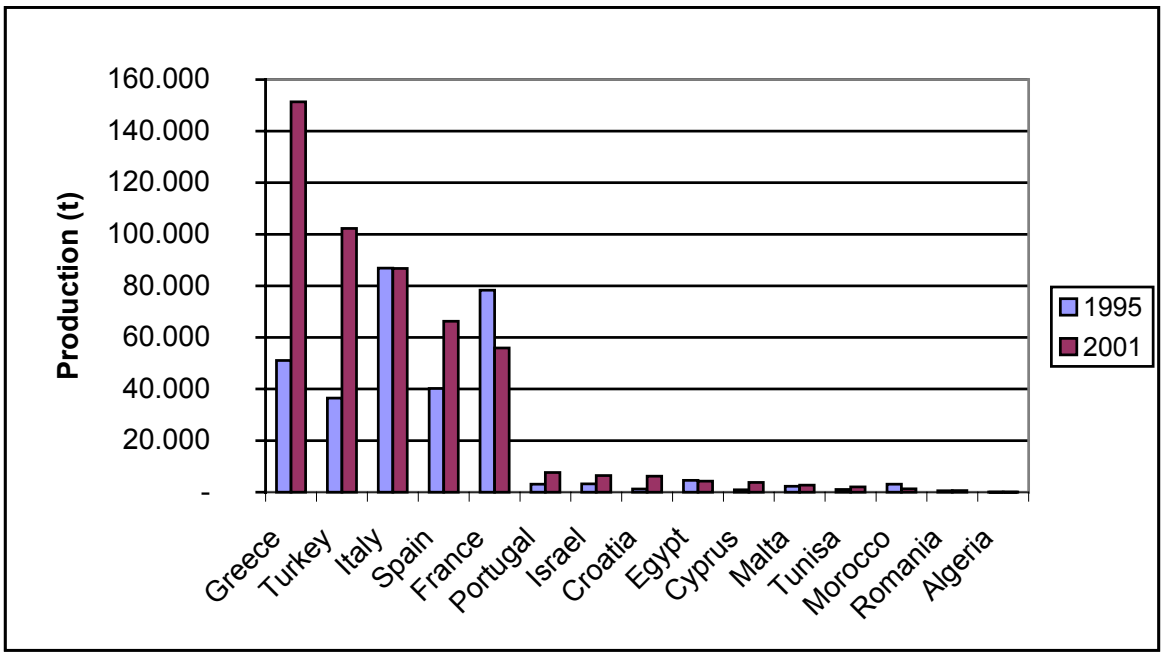

Fig. 1. Aquafeed markets in Mediterranean countries of main species intensively cultured (based on data from Tables 4 and 6).

Business environment

Although the aquafeed sector in Europe and the Mediterranean is growing, it is estimated that it only accounts for 1% of the animal feed sector in Europe (Sabaut, 2003). Mediterranean aquafeed production is present in the main producing countries of carnivorous fishes. This industry can be described as a dynamic sector represented by about 25 feed companies, a significantly higher number of aquafeed companies than in northern Europe where about 6 feed companies operate in UK, Ireland, Norway, Iceland and the Faeroe Islands (Martin, 2000).

In countries like France, Italy or Spain, main aquafeed companies belong to European group leaders in the production of salmonid feeds, e.g. Biomar, Nutreco and Provimi. There are also examples of local feed companies (e.g. Dibaq in Spain or Perseus in Greece); some integrated into aquaculture/agrofood groups, e.g. Feedus into Nireus Group (Greece) or Pinar Feed Industry and Marketing Co. into Pinar Group (Turkey). Few companies combine aquafeed production with the production of other animal compound feeds.

Although the average production of Mediterranean aquafeed factories is estimated to be slightly over 20,000 t, the production among different factories varies from 5,000 to 40,000 t or more. It is

pointed out that in order to adapt to the new scenarios (i.e. production technology changes, growth of companies and the production capacity of their units, higher competition, etc.), the aquafeed companies should have a production of 30,000 t to cover the necessary investment and resources.

Table 3. Intensive fish production in Mediterranean countries in 1995 (source: FAO-FIDI, 2003)

	Trout	Seabream	Seabass	Turbot	Eel	Sea trout	Atl. salmon	Total fish/country
Italy	50,000	3,200	3,600		3,000			59,800
France	48,924	984	2,656	694	180	1,897	894	56,229
Egypt		1,062	755					1,817
Spain	22,000	2,706	461	2,174	214		695	28,250
Greece	1,395	9,387	9,539		659		7	20,987
Turkey	12,689	4,847	2,773				654	20,963
Romania						390		390
Israel	607	230	700					1,537
Bulgaria	650							650
Croatia	277	90	247					614
Morocco	100	590	533		55			1,278
Portugal	948	417	265	82	10			1,722
Malta		550	350	1	3			904
Tunisia		160	230		18			408
Cyprus	98	223	99					420
Algeria			10		20			30
Total/species	137,988	24,446	22,218	2,951	4,159	2,287	2,250	196,299
Estimated FCR†	1.3	2.4	2.7	1.2	1.5	1.5	1.4	
Estimated feed market	179,384	58,670	59,989	3,541	6,239	3,431	3,150	314,404

†FCR are estimations compiled from the aquafeed industry.

Table 4. Estimated aquafeed production in Mediterranean countries in 1995†

	Trout	Seabream	Seabass	Turbot	Eel	Sea trout	Atl. salmon	Total feed/country
Italy	65,000	7,680	9,720		4,500			86,900
France	63,601	2,362	7,171	833	270	2,846	1,252	78,334
Egypt		2,549	2,039					4,587
Spain	28,600	6,494	1,245	2,609	321		973	40,242
Greece	1,814	22,529	25,755		989		10	51,096
Turkey	16,496	11,633	7,487				916	36,531
Romania						585		585
Israel	789	552	1,890					3,231
Bulgaria	845							845
Croatia	360	216	667					1,243
Morocco	130	1,416	1,439		83			3,068
Portugal	1,232	1,001	716	98	15			3,062
Malta		1,320	945	1	5			2,271
Tunisia		384	621		27			1,032
Cyprus	127	535	267					930
Algeria			27		30			57
Total feed/species	179,384	58,670	59,989	3,541	6,239	3,431	3,150	314,404
Estimated FCR††	1.3	2.4	2.7	1.2	1.5	1.5	1.4	

†Based on FAO production data (FAO-FIDI, 2003).

††FCR are estimations compiled from the aquafeed industry.

Table 5. Intensive fish production in Mediterranean countries in 2001 (source: FAO-FIDI, 2003)

	Trout	Seabream	Seabass	Turbot	Eel	Sea trout	Atl. salmon	Total fish/country
Egypt		1,053	841					1,894
Turkey	38,064	12,939	15,546					66,549
Greece	2,590	40,698	25,342		636		23	69,289
Italy	44,000	7,800	9,500		2,500			63,800
France	42,037	1,643	2,721	702	42	2,050	90	49,285
Spain	35,384	9,382	2,307	3,636	339		323	51,371
Israel	600	2,500	150					3,250
Romania	500		0			100		600
Croatia	1,261	940	1,250					3,451
Portugal	1,252	1,761	925	343	7	1		4,289
Cyprus	83	1,278	383					1,744
Malta		1,039	196					1,235
Morocco	80	304	202		35			621
Tunisia		448	461		11			920
Algeria		20			20			40
Total/species	165,851	81,805	59,824	4,681	3,590	2,151	436	318,338
Estimated FCR†	1.0	2.2	2.3	1.1	1.5	1.5	1.3	
Estimated feed market	165,851	179,971	137,595	5,149	5,385	3,227	567	497,745

†FCR are estimations compiled from the aquafeed industry.

Table 6. Estimated aquafeed markets in Mediterranean countries in 2001†

	Trout	Seabream	Seabass	Turbot	Eel	Sea trout	Atl. salmon	Total feed/country
Egypt		2,317	1,934					4,251
Turkey	38,064	28,466	35,756					102,286
Greece	2,590	89,536	58,287		954		30	151,396
Italy	44,000	17,160	21,850		3,750			86,760
France	42,037	3,615	6,258	772	63	3,075	117	55,937
Spain	35,384	20,640	5,306	4,000	509		420	66,259
Israel	600	5,500	345					6,445
Romania	500					150		650
Croatia	1,261	2,068	2,875					6,204
Portugal	1,252	3,874	2,128	377	11	2		7,643
Cyprus	83	2,812	881					3,776
Malta		2,286	451					2,737
Morocco	80	669	465		53			1,266
Tunisia		986	1,060		17			2,062
Algeria		44			30			74
Total feed/species	165,851	179,971	137,595	5,149	5,385	3,227	567	497,745
Estimated FCR††	1.0	2.2	2.3	1.1	1.5	1.5	1.3	

†Based on FAO production data (FAO-FIDI, 2003).
††FCR are estimations compiled from the aquafeed industry.

The relation between fish farmers and aquafeed companies is by far closer than that of customer and supplier. Given the special environment of this developing business, aquafeed companies play an important role in the sector, not only by supplying fish feeds, but also by providing assistance through a wide range of services that are very difficult to find by other means. Thus, most companies give

assistance and advice on aspects such as feeding policy, diagnosis and health management, environmental advice, R&D on new diets and new species, etc.

Aquafeed types and processing technology

Formulated fish feeds can be classified according to target species, growth stage, processing or energy level, although the latter is the most used by the feed manufacturers. Table 7 presents the feeds currently available on the market, classified by criteria and focused on the on-growing stage.

Table 7. Present classification of commercial feeds [updated by authors from Martin (1999)]

	High energy	Middle energy	Low energy
Digestible energy (MJ)	20-22	18-21	15-18
Protein/fat	39-48/22-31	43-58/11-26	30-40/4-13
Processing	Extruder	Extruder-expander-pellet mills	Extruder-pellet mills
Target species	Trout, eel	Seabass, seabream, turbot	Tilapia, carp

The selection of feed type is very variable and will depend to a large extent on the culture conditions of each farm and on the consumer preferences in each country. Thus, feeds with 21-22% fat content are used for marine species and 26-30% for trout, although in some cases (i.e. France) a lower fat content is used. Furthermore, the selection of feed also follows a seasonal pattern, especially in marine fish.

The objective is not only to produce a feed that will achieve maximum growth and minimum feed conversion indexes, but also to address a whole series of factors aimed at obtaining physical characteristics of the feed so it will adapt to the farming systems of the different species, to seek a higher quality for the final product, and to cause minimum environmental impact through feeding. The production systems should also be able to guarantee the traceability and safety of the product at all times.

Challenges for the aquafeed industry in the region

Products and alternative raw materials

When compared to the needs for the production of other terrestrial animals, aquaculture uses only limited quantities of the raw materials that are available globally - only 1% of animal feeds in Europe are for aquaculture (Sabaut, 2003). Thus, there is no risk *a priori* for the supply of the basic raw material. However, due to various crises in the agro-food sector (fundamentally the mad cow disease and dioxins etc.) in recent years the feed companies have had to adapt to various restrictions in the use of raw materials such as the restriction in the use of animal meal or GM plant meals.

It is also necessary to evaluate the availability of natural resources, mainly fish meal and fish oil, which are nowadays indispensable for aquaculture manufactures, and compare the use made by aquaculture with other users (e.g. other animal sector) where it can be accessory. The demand for fish meal and fish oil, as major ingredients in aquafeeds, has steadily grown with the development of the aquaculture industry in the last decades. According to IFFO (Barlow, 2002) in the year 2002 aquaculture already used 34% and 56% of world fish meal and fish oil production, respectively. The prediction for the year 2010 is that aquaculture will use 48% and 79% of world fish meal and fish oil production, respectively. In spite of this increased demand, the world production of fish meal and fish oil remains more or less stable (about 6.5 million t of fish meal and 1.25 million t of fish oil), although with some serious fluctuations (up to 30%) due to phenomena such as "El Niño". This also raises concern about the uncertainty of future market availability and prices.

Aware of this situation and due to the competitiveness of the sector, the aquafeed manufactures, by improving FCR, are reducing the amount of fish meal and fish oil in their feeds. In addition, a lot of research has shown that vegetable sources of protein (e.g. soya, sunflower, cereal glutens, etc) and oils (soya, olive, rapeseed, etc) are usable in aquafeeds in varying proportions. The partial supplementation of fish meal and fish oil in aquafeeds is already a reality. Thus, some companies declare to be increasing their ratio in their feeds. For example the proportion of vegetable oil used in total fish feed production in Nutreco Aquaculture doubled from 2001 to 2002, from 5.5% to 11.4%. In salmon feeds a typical supplementation level is one-third but it can be as high as two-thirds vegetable oil to one-third fish oil (Frazer, 2003).

This partial substitution means not only a reduction and stability on the costs of feeds, but also helps to reduce the dependence and pressure on these two natural resources. However, in order to increase the present low ratios of replacement of fish meal and fish oil by other vegetable protein and fat sources, more research is needed in order to ensure that the substitutions do not affect growth, food conversion, liver functions and quality of the final product.

Other challenges

The challenges for the aquafeed industry in the Mediterranean are linked to the aquaculture sector itself and involve all issues threatening future development, including the following:

(i) Re-organisation (*concentration*) of aquafeed companies: in order to increase production efficiency, R&D optimisation, purchasing power, bargaining power with large customers, logistics.

(ii) Adaptation to the consumer and social demands: consumer demand of high quality products at low/affordable prices, concerns for healthy food, adaptation to ISO's and HACCP quality certification and traceability throughout the whole production process.

(iii) Co-operation with fish farmers in common projects: to attend R&D projects together, based on common objectives such as fish quality and safe products for the market, use of drugs, environmental issues, etc.

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