

## ÍNDICE DE CONTENIDOS

### CAPÍTULO 1

Introducción general	13
1.1 Generalidades	15
1.2 Situación actual de la acuicultura mundial	17
1.3 La dorada en la acuicultura	18
1.4 La nutrición de la dorada	24
1.4.1 Coeficientes metabólicos	28
1.4.2 Necesidades de Mantenimiento y Eficiencias	28
1.4.3 Modelos de crecimiento	32
1.4.4 Composición corporal	34
1.4.5 Otras especies	35

### CAPÍTULO 2

Justificación y objetivos	39
---------------------------	----

### CAPÍTULO 3

Resumen de experimentos	43
-------------------------	----

### CAPÍTULO 4

A proposal for modeling the thermal-unit growth coefficient and feed conversion ratio as functions of feeding rate for gilthead sea bream ( <i>Sparus aurata</i> , L.) in summer conditions.	47
Abstract	49
Introduction	50
Materials and Methods	54
Experimental facilities	54
Experimental Design	54
Modeling and Statistical Analysis	56
Discussion	63
Conclusion	71
Acknowledgments	71
References	72

## CAPÍTULO 5

Protein deposition and energy recovery in gilthead sea bream ( <i>Sparus aurata</i> ): evaluation of nutritional requirements. _____	77
Abstract _____	79
Introduction _____	80
Material and methods _____	82
Experimental facilities and design _____	82
Chemical analysis _____	83
Calculations and Statistical Analysis _____	85
Results _____	86
Digestibility _____	86
Whole body composition _____	86
Nutrient intake and retention curves _____	87
Maintenance requirements and efficiency _____	90
Discussion _____	92
Whole body composition _____	92
Retention curves _____	93
Digestible Energy for maintenance _____	94
Digestible Protein for maintenance _____	95
Efficiency _____	95
Acknowledgments _____	100
Bibliography _____	100

## CAPÍTULO 6

Defining optimum diets for gilthead sea bream ( <i>Sparus aurata</i> ) using multifactorial approaches. _____	103
Abstract _____	109
Introduction _____	110
Material and methods _____	112
Retention, Maintenance and efficiencies _____	112
Whole body composition _____	113
Results _____	117
Discussion _____	120
Limits of the study _____	126
Effect of weight. _____	127
Effect of whole body composition. _____	128
Temperature effect _____	131
Maintenance needs _____	132

Effect of net energy efficiency ( $k_e$ ). _____	134
Effect of net protein efficiency ( $k_p$ ). _____	136
Diets _____	137
References _____	141

## CAPÍTULO 7

Discusión general _____	149
-------------------------	-----

## CAPÍTULO 8

Conclusiones _____	167
--------------------	-----

## CAPÍTULO 9

Referencias bibliográficas _____	173
----------------------------------	-----



# ÍNDICE DE FIGURAS

## CAPÍTULO 1

### Introducción general

Figura 1.- Producción mundial de la pesca y la acuicultura. F.A.O. (2014)	17
Figura 2.- Producción de dorada en España. APROMAR (2015)	19
Figura 3.- Variación de precios de la dorada según talla mercamadrid. APROMAR (2015)	20
Figura 4.- Índices de Conversión Alimentario (elaboración propia con datos de APROMAR)	21
Figura 5.- Costes de alimentación y alevines. STECF (2014)	21
Figura 6.- Ingresos totales, costes de producción y margen de beneficio neto de la dorada y lubina. STECF (2014)	22
Figura 7.- Cadena de valor de la dorada, campaña 2010 y 2011 (Tragsatec 2012).	23

## CAPÍTULO 4

### A proposal for modeling the thermal-unit growth coefficient and feed conversion ratio as functions of feeding rate for gilthead sea bream (*Sparus aurata*, L.) in summer conditions.

Figure 1.- Methodology for determining critical points in the graphs drawing thermal growth coefficient and feed conversion ratio in function of feeding rate.	59
Figure 2.- Thermal growth coefficient response to increasing levels of feeding rate and the response curve of asymptotic and quadratic models considering six feeding trials in gilthead sea bream.	61
Figure 3.- Feed conversion ratio simulation responses as functions of feeding rate for several initial body weights of gilthead sea bream (84 days at 23°C) using asymptotic and quadratic models.	68
Figure 4.- Economic profitability index simulation responses as functions of feeding rate for several initial body weights of gilthead sea bream (84 days at 23°C) using asymptotic and quadratic models.	69
Figure 5.- Comparison of thermal growth coefficient–feeding rate curves obtained in several fish species by some authors.	70

## CAPÍTULO 5

### Protein deposition and energy recovery in gilthead sea bream (*Sparus aurata*): evaluation of nutritional requirements.

Figure 1.- Whole body composition of gilthead sea bream from 23 to 400 g.	87
Figure 2.- Energy recovery response curves for different feeding levels of gilthead sea bream below and above 110g of body weight.	89
Figure 3.- Protein deposition response curves for different feeding levels of gilthead sea bream below and above 110g of body weight.	90
Figure 4.- Energy efficiency of gilthead sea bream fed at different feeding levels and fish size.	91
Figure 5.- Protein efficiency of gilthead sea bream fed at different feeding levels and fish size.	91
Figure 6.- Schematic representation of energy flows through an animal (based on NRC 1981) and mean values for higher feeding rates and percentages of energy for small (<110g) and large (>110g) gilthead sea bream.	98

## CAPÍTULO 6

### Defining optimum diets for gilthead sea bream (*Sparus aurata*) using multifactorial approaches.

Figure 1.- Energy recovery response curve from two authors and situations.	122
Figure 2.- Protein recovery response curve according to Jauralde <i>et al.</i> (2015) and Lupatsch <i>et al.</i> (2003) respectively.	122
Figure 3.- Whole body composition of gilthead sea bream.	129
Figure 4.- Lipid content limits related to the LC:PC ratio	130
Figure 5.- Energy requirements ( $\text{kJ fish}^{-1} \text{ day}^{-1}$ ) for maintenance for several body weights and temperatures	132
Figure 6.- Protein requirements by fish for maintenance for several body weights.	133
Figure 7.- Net energy efficiency for growth ( $k_e$ ) for several TGCs and body weights at 21°C	135
Figure 8.- Net protein efficiency for growth ( $k_p$ ) for several TGCs and body weights at 21°C	136

Figure 9.- Different diet designs, FCRs and associated efficiencies for several growth (TGCs), temperatures and based on the results reached by Jauralde *et al.* and Lupatsch *et al.* \_\_\_\_\_ 139

## CAPÍTULO 7

### Discusión general

Figura 1.- Thermal Growth Coeficient para distintos FR y pesos de doradas consumiendo un pienso con 465 g kg <sup>-1</sup> de proteína digestible y 16 MJ kg <sup>-1</sup> de energía digestible. _____	154
Figura 2.- <i>Feed Conversion Ratio</i> para distintos FR y pesos de doradas consumiendo un pienso con 465 g kg <sup>-1</sup> de proteína digestible y 16 MJ kg <sup>-1</sup> de energía digestible. _____	155
Figura 3.- <i>Economic Profit Index</i> para distintos FR y pesos de doradas consumiendo un pienso con 465 g kg <sup>-1</sup> de proteína digestible y 16 MJ kg <sup>-1</sup> de energía digestible. _____	156
Figura 4.- Modelización de las perdidas diarias de energía y proteína de doradas en ayuno. _____	158
Figura 5.- Eficiencia Bruta de la proteína digestible para doradas de distinto peso _____	161
Figura 6.- Eficiencia Bruta de la energía digestible para dorada de distinto peso _____	161
Figura 7.- Eficiencia Bruta de la energía digestible según Lupatsch <i>et al.</i> (2003) _____	162
Figura 8.- Eficiencia marginal de la proteína según Jauralde <i>et al.</i> (2015b) _____	163
Figura 9.- Eficiencia marginal de la energía según Jauralde <i>et al.</i> (2015b) _____	164





# ÍNDICE DE TABLAS

## CAPÍTULO 1

### Introducción general

Tabla 1. Niveles de Proteína y Energía Digestible para dorada de hasta menos de 200 gramos _____	25
Tabla 2. Niveles de Proteína y Energía Digestible para dorada de hasta más de 200 gramos _____	26
Tabla 3.- Necesidades nutritivas y ratio PD/ED para doradas a 23°C. (Lupatsch <i>et al.</i> , 2003a) _____	35
Tabla 4.- Necesidades de la <i>Seriola quinqueratiada</i> . (Watanabe <i>et al.</i> , 2000). _____	36

## CAPÍTULO 3

### Resumen de experimentos

Tabla 1.- Resumen de experimentos. _____	45
--	----

## CAPÍTULO 4

A proposal for modeling the thermal-unit growth coefficient and feed conversion ratio as functions of feeding rate for gilthead sea bream (*Sparus aurata*, L.) in summer conditions.

Table 1.- Experimental conditions and durations of six feeding trials in gilthead sea bream fed at different feeding rate. _____	55
Table 2.- Feeding rate, growth, feed conversion ratio and survival results for six trials in gilthead sea bream fed at different feeding rates. _____	59
Table 3.- Estimate of feed rate, thermal-unit growth coefficient and feed conversion ratio (FCR) for maximum economic profitability index and minimum FCR using an asymptotic model and a quadratic model (considering 4.5 €/kg as the value of fish and 0.75 €/kg as the cost of the diet (84 days of growth at 23°C) _____	63
Table 4.- Asymptotic and quadratic models for TGC-FR developed in some fish species using data from several authors. _____	65

## CAPÍTULO 5

### Protein deposition and energy recovery in gilthead sea bream (*Sparus aurata*): evaluation of nutritional requirements.

Table 1.- Experimental conditions and durations of six feeding trials in gilthead sea bream fed at different feeding rate. _____	83
Table 2.- Protein deposition and energy recovery of sea bream fed at different feeding levels. _____	88

## CAPÍTULO 6

### Defining optimum diets for gilthead sea bream (*Sparus aurata*) using multifactorial approaches.

Table 1.- Daily energy and protein requirements at 21°C (Jauralde <i>et al.</i> , 2015) _____	118
Table 2.- Daily energy and protein requirements at 25°C (Jauralde <i>et al.</i> , 2015) _____	118
Table 3.- Dietary protein at 16, 18 and 20 MJ/Kg, Feeding Rate and Feed Conversion Rate at 21 °C based on Jauralde <i>et al.</i> (2015). _____	119
Table 4.- Dietary protein at 16, 18 and 20 MJ/Kg, Feeding Rate and Feed Conversion Rate at 25 °C based on Jauralde <i>et al.</i> (2015). _____	119
Table 5.- Energy and protein requirements, diet at 16 MJ/Kg and FR and FCR at 21 °C based on Lupatsch <i>et al.</i> (2003b) with the fixed value of $k_p=0.47$ _____	124
Table 6.- Energy and protein requirements, diet at 16 MJ/Kg and FR and FCR at 25 °C based on Lupatsch <i>et al.</i> (2003b) with the fixed value of $k_p=0.47$ _____	124
Table 7.- Energy and protein requirements, diet at 16 MJ/Kg and FR and FCR at 21 °C based on Lupatsch <i>et al.</i> (2003b) with variable $k_p$ _____	125
Table 8.- Energy and protein requirements, diet at 16 MJ/Kg and FR and FCR at 25 °C based on Lupatsch <i>et al.</i> (2003b) with variable $k_p$ _____	125
Table 9.- Requirements of energy and protein, diet at 16 MJ/Kg and FR and FCR for a TGC=0.00150 at 21 °C allowing an increase of the LC:PC ratio together with equations by Jauralde <i>et al.</i> (2015). _____	131

## Discusión general

Tabla 1.-Parametros de crecimiento y niveles de energía previstos con el consumo de un pienso de PD/ED de  $29.04 \text{ g MJ}^{-1}$  con una PD de  $465 \text{ g kg}^{-1}$  y una energía de  $16 \text{ MJ kg}^{-1}$  y 84 días de crecimiento. \_\_\_\_\_ 152

