THE USE OF PREMIUM YEAST EXTRACT PROSAF® IN REDUCED FISHMEAL DIETS FOR THE WHITE-LEG SHRIMP (*L. vannamei*)

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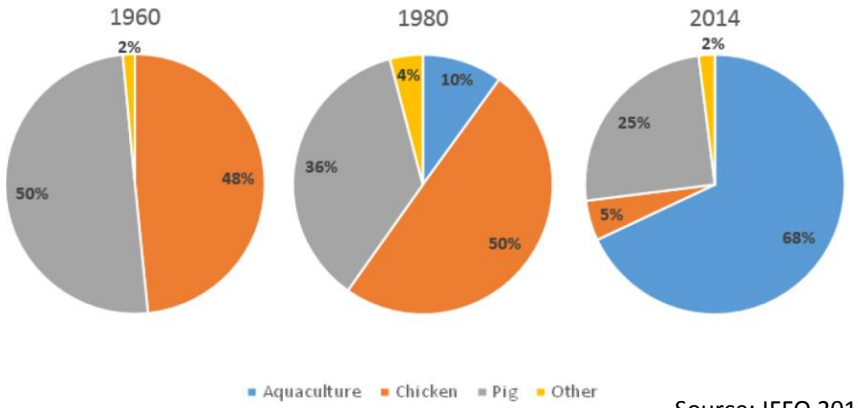
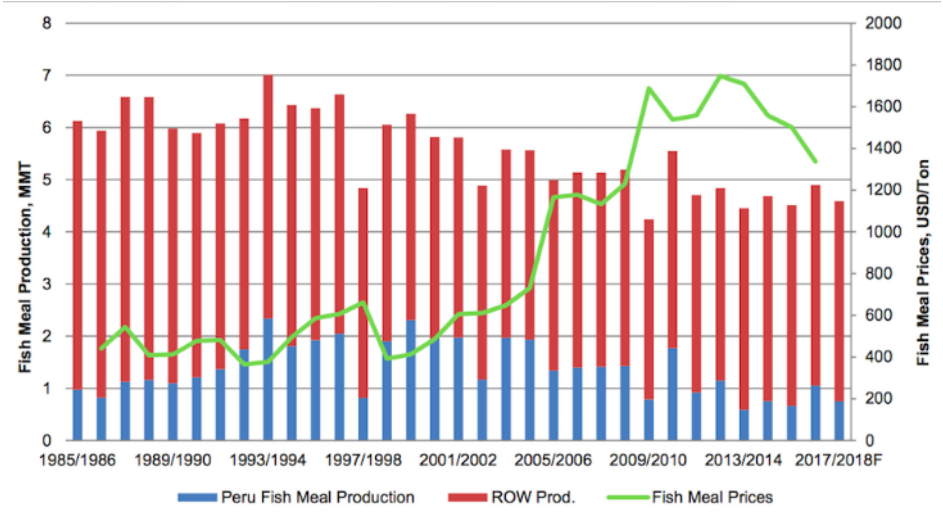
ASSOCIAÇÃO BRASILEIRA DE CRIADORES DE CAMARÃO

Market context – Fish Meal



Source: IFFO 2017



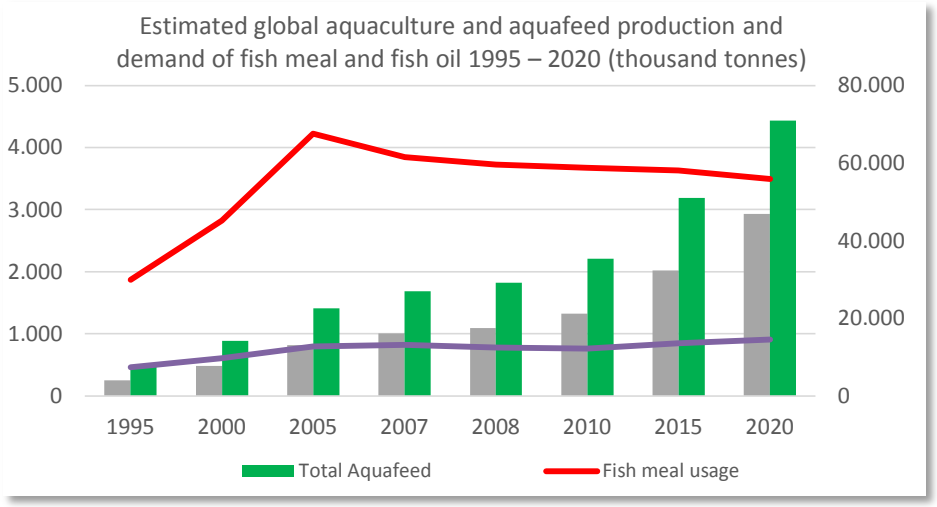
FISH MEAL USAGE in AQUACULTURE

- Allowed aquaculture expansion and feed efficiency gain
- ↑ demand within the aquaculture growth (fed species; carnivorous and marine)
- Considered as the best source of nutrients for aquaculture (nutrient balance and digestibility)

FISH MEAL PRODUCTION - SUPPLY AND PRICES

- ↑ demand + limited supply (fisheries) = ↑ prices
- Substitute raw materials prices are following similar trend due to elevated demand and competition with other productive sectors
- Pressure to develop new protein sources in order to keep feed prices (feed = 50-70% of costs)

Market context – Fish Meal

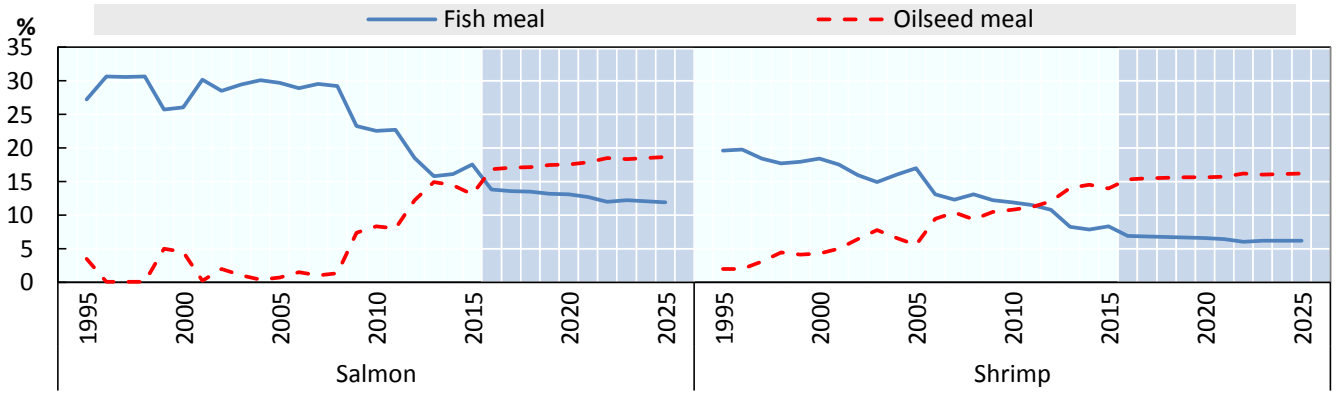


Source: Adapted Tacon, Hasan & Metian (2011)

THE CHALLENGE

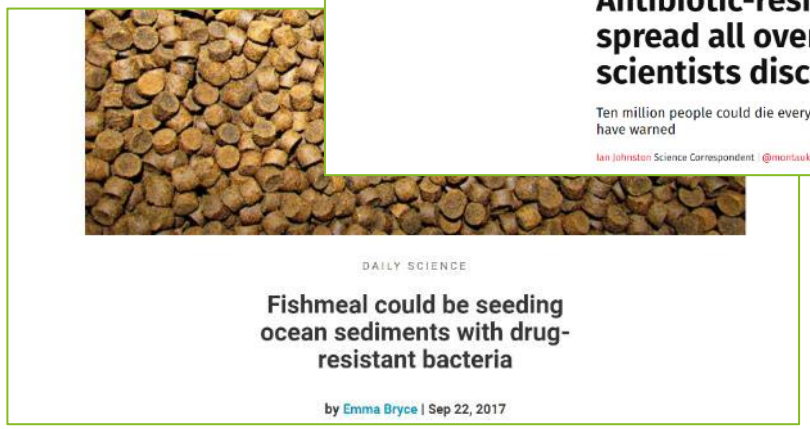
- Aquaculture and aquafeed production has to growth to support fish consumption
- ↑ demand within high value species (shrimp, salmon, carnivorous and marine fish)
- Keep industry profitability and competitiveness in the international market

Share of fishmeal consumption in salmon and shrimp feeds



Source: Adapted from OECD/FAO (2016)

Market Context – Sustainability



SUSTAINABILITY AND SAFETY ISSUES ARE ALSO PUSHING THE INDUSTRY TOWARDS MORE SUSTAINABLE SOLUTIONS

Main drivers to develop fish meal replacement strategies

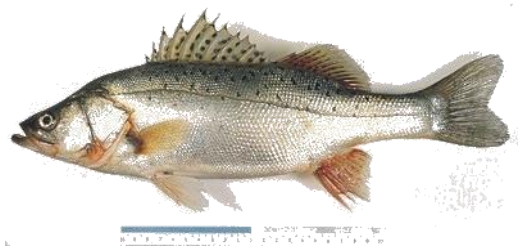
Fish Meal

- Origin and source
- Nutritional profile
- Freshness
- Price
- Targeted usage and inclusion level

Substitute ingredients

- Antinutritional factors
- Nutritional imbalances
- Feed processing technology
- Price and availability
- Impact in the final product (fillet)

Targeted species



- Digestive physiology
- Life-stage
- Production system
- Nutritional requirements

Challenges related to alternative & plant based proteins in aquaculture

Soy meal & by-products

Rapeseed meal

Peanut meal

Cotton-seed meal

Sunflower meal

Lupins meal

ANTINUTRITIONAL FACTORS

Proteinase inhibitors, lectins, phytic acid, saponins, phytoestrogens, antivitamins, phytosterols, allergens, alkaloids, gossypol, tannins, cyanogens, erucic acid, glucosinates, mycotoxins etc.

- **Enzymatic inhibition Reduced protein, lipid and starch digestibility.**
- **Negative effects on palatability and feed intake**
- **Histological alterations and inhibit glucose transport into intestinal epithelium**
- **Increased uptake of harm substances as allergens. Enteritis.**
- **Altered liver and kidney functions.**
- **…etc.**

Adapted, NRC (2011)

Growth & performance impacts

	1	2	3	4	5	6
Fish meal level	422	305	258	211	164	117
Pork meat meal	0	145.5	203.6	261.8	320	378.2
Soybean meal	64.4	64.4	64.4	64.4	64.4	64.4
Squid liver meal	20	20	20	20	20	20
FCR	1.43	1.52	1.53	1.72	1.84	1.82
Survival	90	95	93	91	93	95
Feed Intake (g/shrimp)	5.55	5.45	5.3	5.47	5.62	5.45
Weight Gain (%/d)	5.1	4.9	4.8	4.6	4.5	4.5
Apparent digestibility DM	81.92	77.77	72.61	67.31	70.35	70.37
Apparent digestibility Protein	85.34	82.26	78.48	73.15	74.27	73.47
Apparent digestibility Energy	87.65	84.42	82.18	79.33	79.51	79.18
Apparent digestibility Lipids	93.56	88.77	86.17	84.07	83.87	83.76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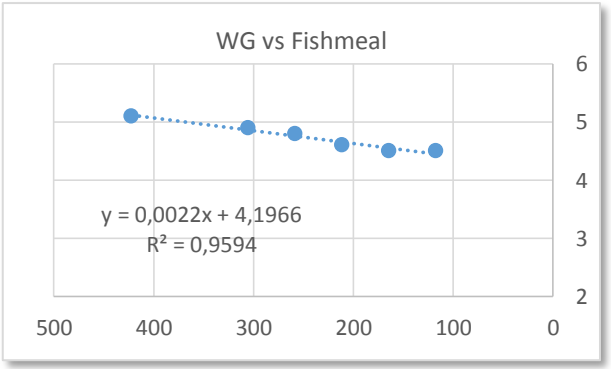
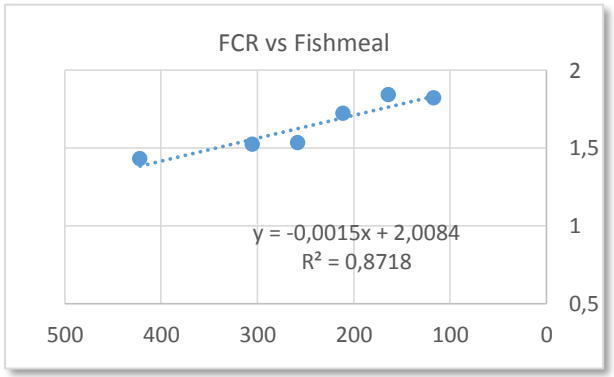
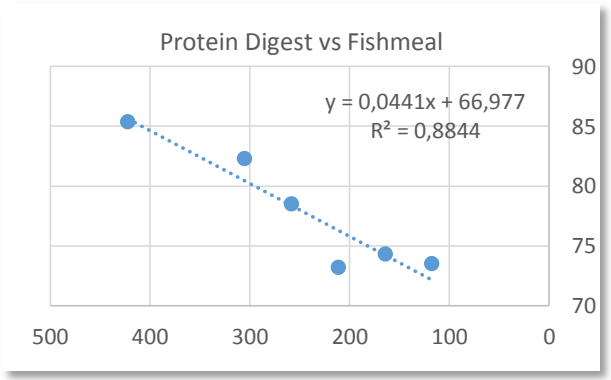
ELSEVIER

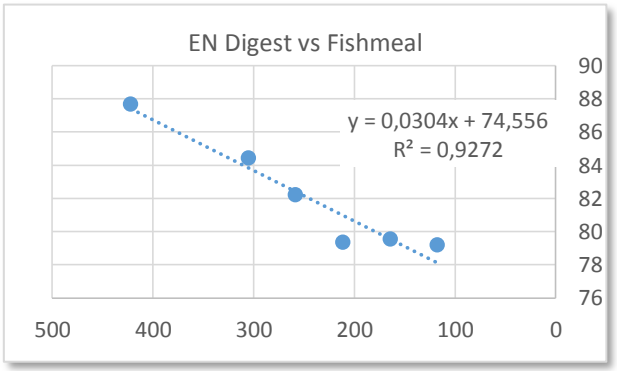
Partial replacement of fish meal by porcine meat meal in practical diets for Pacific white shrimp (*Litopenaeus vannamei*)

Crisantema Hernández [a,*], Miguel A. Olvera-Novoa [b], Karla Aguilar-Vejar [a], Blanca González-Rodríguez [a], Isabel Abdo de la Parra [a]



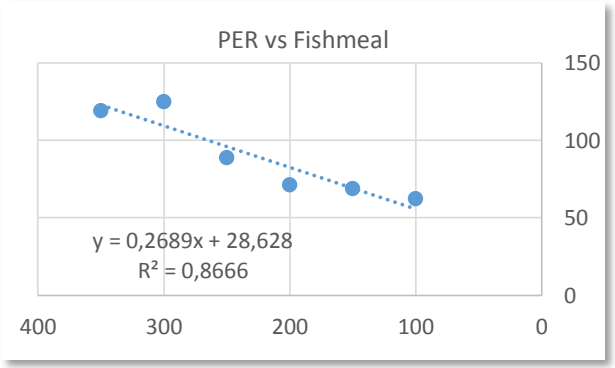


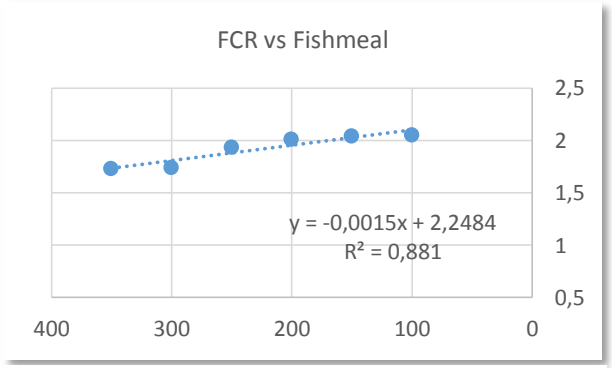


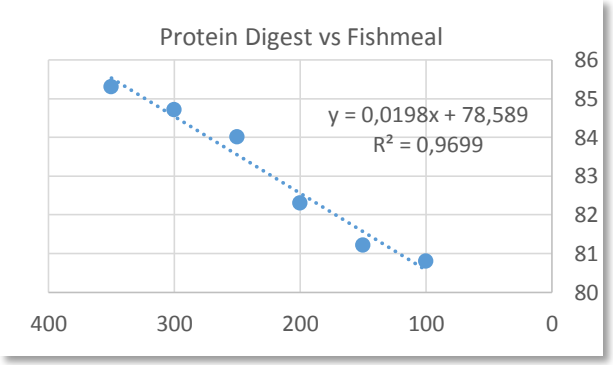


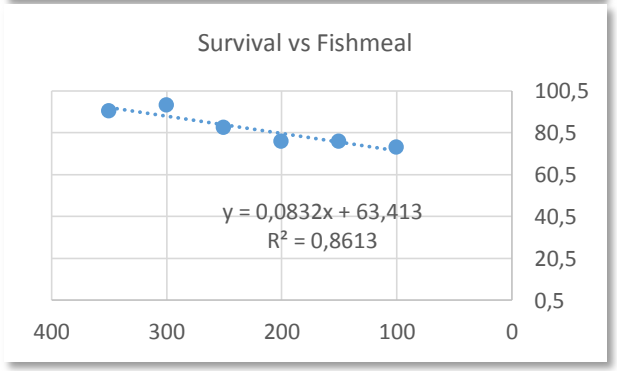
Growth & performance impacts

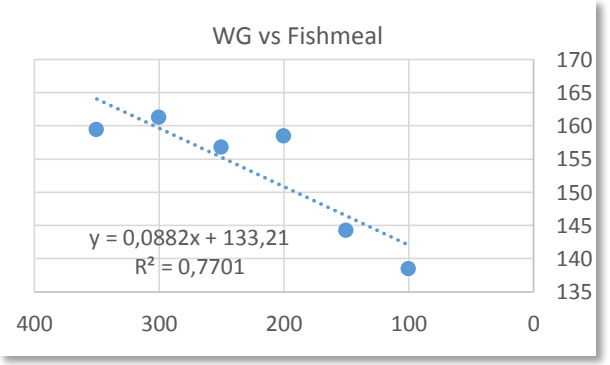
	1	2	3	4	5	6
Fish meal level	350	300	250	200	150	100
Peanut Meal	0	70	140	210	280	350
FCR	1.73	1.74	1.93	2.01	2.04	2.05
Survival	90.7	93.5	82.9	76.2	76.2	73.3
Protein Efficiency Ratuo	119.1	125	88.7	71	68.7	62.3
Weight Gain (%)	159.4	161.2	156.7	158.4	144.2	138.4
Apparent digestibility DM	69.1	68	66.4	66	65.1	64.2
Apparent digestibility Protein	85.3	84.7	84	82.3	81.2	80.8











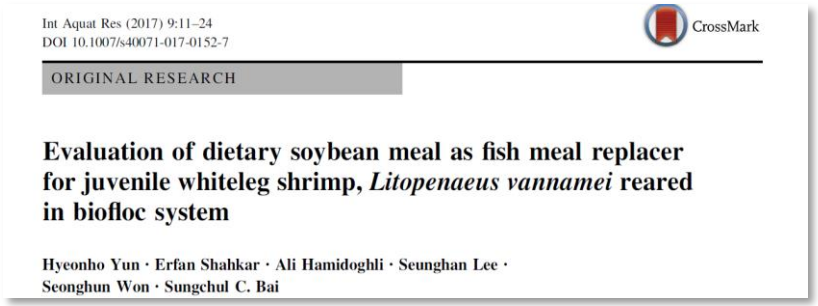
Aquaculture Research, 2012, 43, 745–755 doi: 10.1111/j.1365-2109.2011.02883.x

Partial replacement of fish meal with peanut meal in practical diets for the Pacific white shrimp, *Litopenaeus vannamei*

Xiang-he Liu, Ji-dan Ye, Kun Wang, Jiang-hong Kong, Wei Yang & Lei Zhou
Xiamen Key Laboratory for Feed Quality Testing and Safety Evaluation, Fisheries College of Jimei University, Xiamen, China

Growth & performance impacts

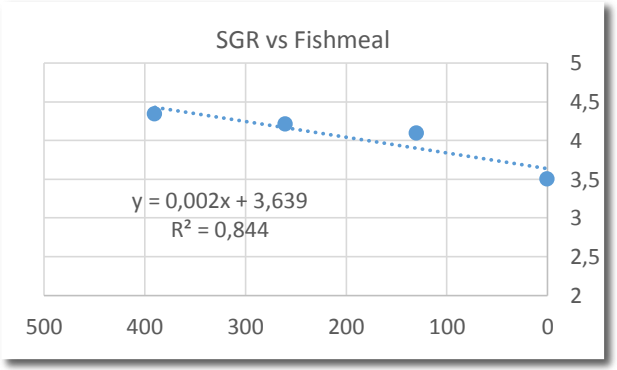
	1	2	3	4
Fish meal level	390	260	130	0
Soybean meal	0	159	322	481
FCR	1.06	1.09	1.17	1.59
Survival	84.2	89.1	89.7	86.7
Specific Growth rate (day)	4.34	4.21	4.09	3.5

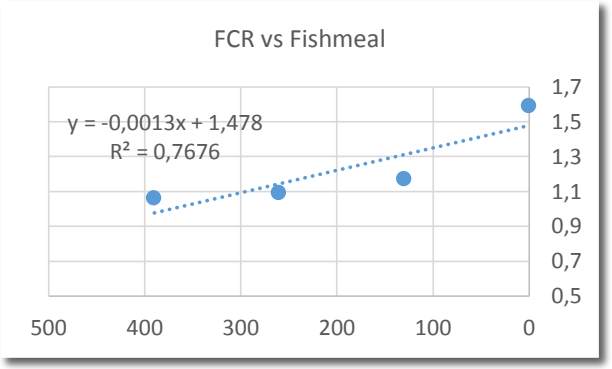

Int Aquat Res (2017) 9:11–24
DOI 10.1007/s40071-017-0152-7

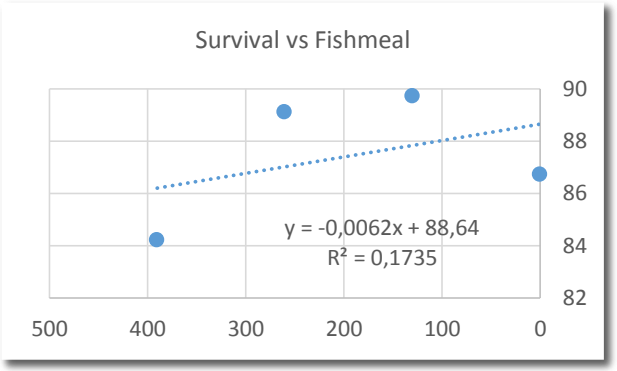
ORIGINAL RESEARCH

Evaluation of dietary soybean meal as fish meal replacer for juvenile whiteleg shrimp, *Litopenaeus vannamei* reared in biofloc system

Hyeonho Yun · Erfan Shahkar · Ali Hamidoghli · Seunghan Lee · Seonghun Won · Sungchul C. Bai







Growth & performance – the danger zone

40	38	36	34	32	30	28	26	24	22	20	18	16	14	12	10	8	6	4	2	0

Challenges limiting fish meal replacement in aquafeeds

- **FEED challenges**
  - Reduced attractiveness & palatability
  - Reduced feed intake
  - Impaired digestion
  - Reduced digestibility
  - Feed processing limitations
  - Logistics & supply chain
  - Price

↓GROWTH PERFORMANCE & FEED EFFICIENCY

Picture: cdn.shape.com

- **FIELD challenges**
  - Stress factors (crowding, temperature, salinity, etc.)
  - Feeding procedures
  - Pathogen pressure

↓ HEALTH STATUS, IMMUNO COMPETENCY & ↑ MORTALITY

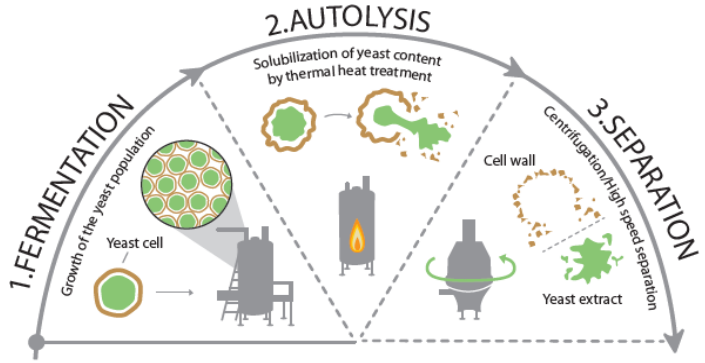
Alternative protein sources needs a secret weapon !

- ↑ Palatability & feed intake
- ↑ Protein digestibility
- ↑ Growth performance
- ↑ Health & immune benefits

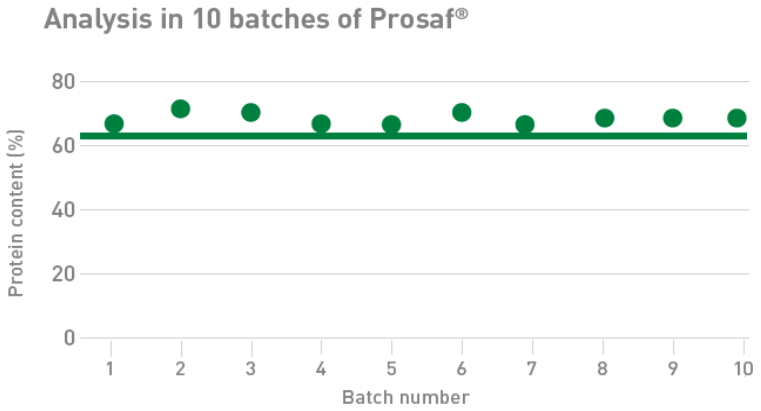
Prosaf® 632

Prosaf® is a premium yeast extract obtained from primary culture of a proprietary *Saccharomyces cerevisiae* baker's yeast strain.

Full process control
Primary fermentation

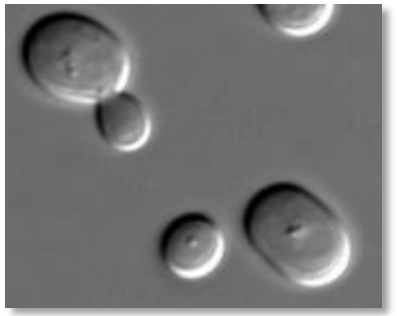


Consistent high protein content > 63%



- Controlled production with standardized parameters
- Specific process to ensure high protein content (>63%)
- High quality batch-to-batch consistency

Yeast extract (Prosaf®) analytical composition



Cytosolic part of baker's yeast strain *Saccharomyces cerevisiae*

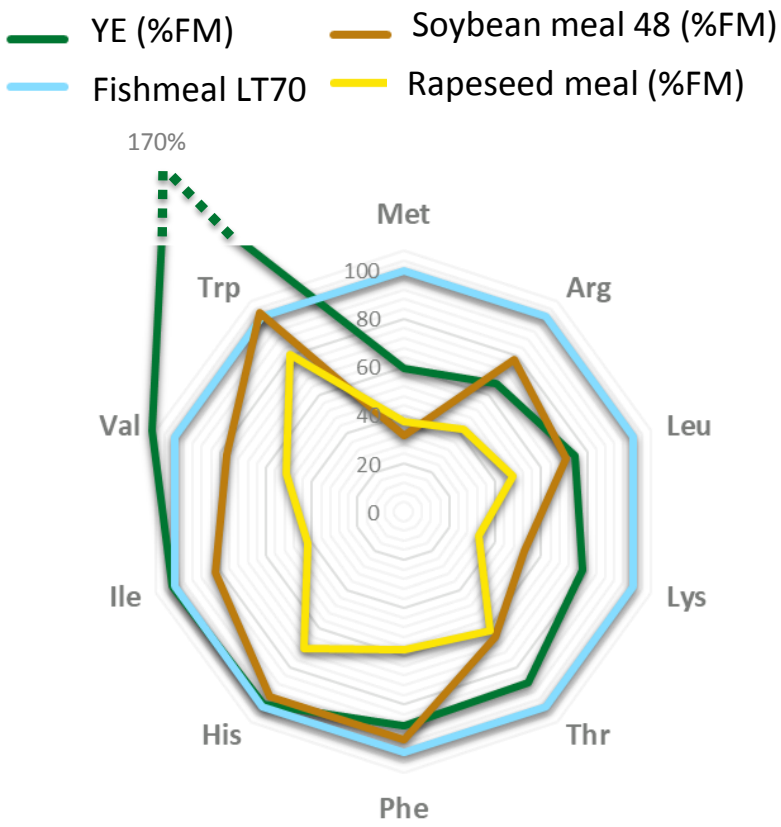
	Yeast extract Prosaf®
Dry matter	96.1%
Crude protein (Nx6.25)	> 63%
Lipid	< 1%
Gross energy	19.4 kJ/g
Ash	7.3%
Nucleic acid	7.7%
Phosphorus	1.3%
Free amino acids	26%

mg/kg	Minerals
Calcium	763
Phosphorus	12880
Potassium	24700
Magnesium	1400
Sodium	2720
Zinc	300
Manganese	7
Iron	74
Copper	< 5

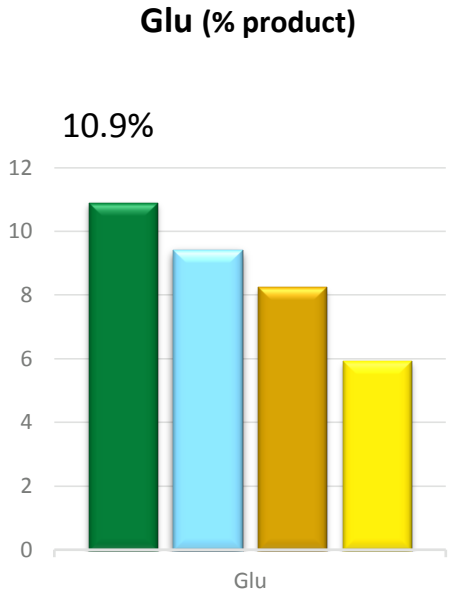
Yeast extract (Prosaf®) analytical composition

- **Essential amino acid composition**

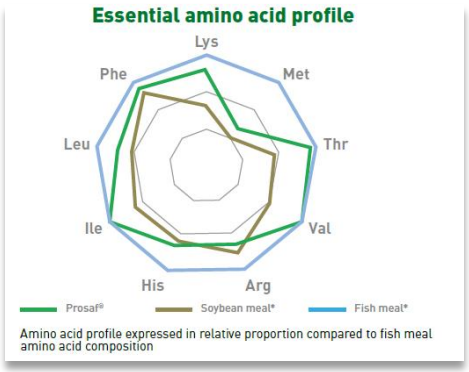
In % relative to FM composition

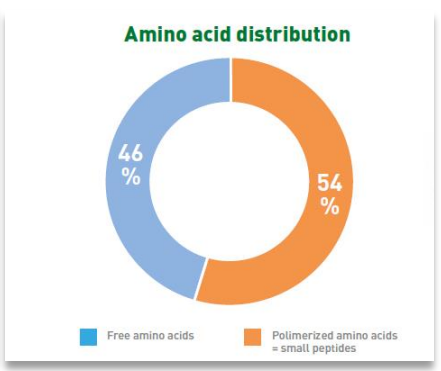


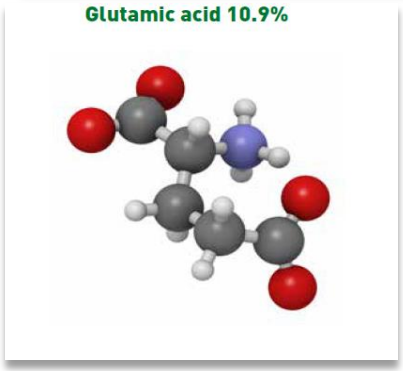
- **Non-essential amino acid**

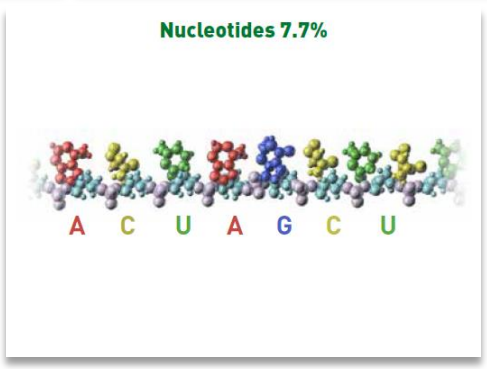


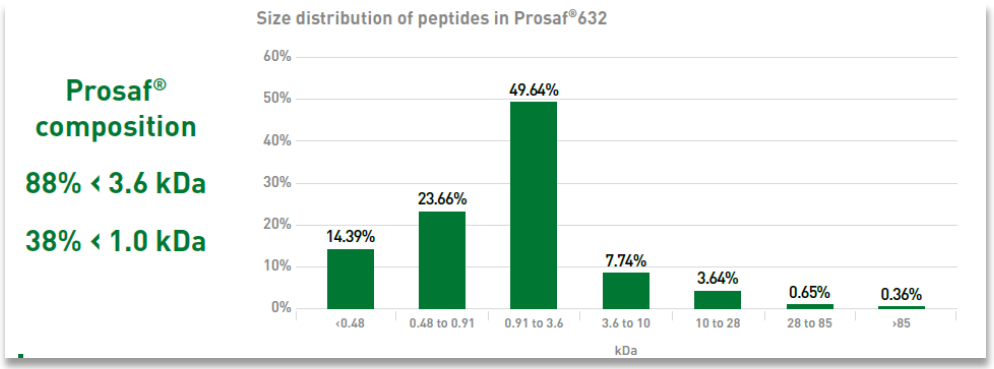
Prosaf® 632 – Key Features











Essential amino acids

- Rich profile of essential amino acids
- Highly available forms – 46% free

Functional compounds

- More than 10% of Glutamic acid
- 7.7% of total nucleotides from yeast cell content

Physical characteristics

- Low molecular size peptides with potential bioactivity

Prosaf's total free amino acids composition

Essential amino acids required for growth and development in shrimp

Amino acid	PROSAF	Fishmeal (anchovy)*	Fish Hydrolyzate *	Krill meal*	Squid liver meal*	Poultry By-product (feed)*	Hydrolized feather meal*	Blood meal spray dried*
	%	%	%	%	%	%	%	%
Arginine	1.30	0.05	0.05	0.39	0.00	0.00	0.00	0.00
Histidine	0.20	0.48	0.18	0.00	0.08	0.05	0.00	0.00
Leucine	2.60	0.08	0.24	0.00	0.06	0.08	0.00	0.00
Isoleucine	1.40	0.00	0.07	0.00	0.00	0.00	0.00	0.00
Lysine	1.00	0.08	0.18	0.00	0.08	0.06	0.00	0.00
Methionine	0.70	0.00	0.08	0.00	0.00	0.00	0.00	0.00
Phenylalanine	1.60	0.05	0.09	0.00	0.00	0.00	0.00	0.00
Threonine	0.90	0.00	0.06	0.00	0.00	0.00	0.00	0.00
Tryptophan	0.30							
Valine	1.60	0.08	0.24	0.00	0.06	0.08	0.00	0.00
TOTAL free aa	**26.22**	**1.18**	**1.98**	**1.13**	**0.51**	**0.50**	**0.00**	**0.00**
TOTAL free essential aa	**11.60**	**0.82**	**1.19**	**0.39**	**0.28**	**0.27**	**0.00**	**0.00**

*Suresh, Vasagam & Nates 2011

Prosaf's total free amino acids composition

Key amino acids involved in chemo-attraction in shrimp

Amino acid	PROSAF	Fishmeal (anchovy)*	Fish Hydrolyzate*	Krill meal*	Squid liver meal*	Poultry By-product (feed)*	Hydrolized feather meal*	Blood meal spray dried*
	%	%	%	%	%	%	%	%
Arginine	1.30	0.05	0.05	0.39	0.00	0.00	0.00	0.00
Alanine	3.40	0.16	0.30	0.06	0.16	0.16	0.00	0.00
Glutamic acid	5.50	0.08	0.19	0.00	0.07	0.00	0.00	0.00
Glycine	0.50	0.05	0.13	0.32	0.00	0.07	0.00	0.00
TOTAL free aa	**26.22**	**1.18**	**1.98**	**1.13**	**0.51**	**0.50**	**0.00**	**0.00**
TOTAL attractants	**10.70**	**0.34**	**0.67**	**0.77**	**0.23**	**0.23**	**0.00**	**0.00**

*Suresh, Vasagam & Nates 2011, Key palatability amino acids (Lee & Meyers, 1997)

Shrimp
In vivo trials results

1. In vivo assessment of Prosaf® nutrients and energy digestibility Prosaf®

Digestibility trial:

- Whiteleg shrimp body weight: 14 ± 1 g
- Tests in quadruplicates
- 20% of test ingredients included in a shrimp reference formula (extruded pellets)
- Inert marker (yttrium oxide)
- Conducted at Sparos Lda (Portugal)

- **Apparent digestibility coefficient (ADC) of nutrients and energy:**

	Prosaf®	Fishmeal LT70	Soybean meal	Rapeseed meal	ANOVA
Protein (%)	88.9^{a}	87.1^{a}	84.4^{a}	53.5^{b}	p<0.01
Energy(%)	83.2^{ab}	86.9^{a}	80.8^{b}	57.5^{c}	p<0.01
Lipid(%)	90.3^{a}	88.2^{a}	77.7^{b}	72.1^{b}	p<0.01




Fishmeal LT70, Norvik 70, Sopropêche, France.
Dehulled solvent extracted soybean meal, Cargill, Spain.
Defatted rapeseed meal, Premix, Portugal.

- Digestibility of **protein and energy** of **Prosaf®** is very good and is **similar** to that of **FM** and **SBM** and **higher** than that of **RSM**.
- Digestibility of **lipid content** of **Prosaf®** is **similar** to that of **FM** and **higher** than that of **SBM** and **RSM**.

1. In vivo assessment of Prosaf® nutrients and energy digestibility Prosaf®

- **ADC of essential amino acids:**

	Prosaf®	Fishmeal LT70	Soybean meal	Rapeseed meal	ANOVA
Arginine (%)	96.4^{ab}	97.9^{a}	94.8^{b}	83.3^{c}	p<0.01
Histidine (%)	97.4^{a}	96.3^{a}	94.7^{a}	85.9^{b}	p<0.01
Isoleucine (%)	98.5^{a}	97.7^{a}	94.6^{b}	83.7^{c}	p<0.01
Leucine (%)	96.8^{ab}	98.1^{a}	94.5^{b}	84.8^{c}	p<0.01
Lysine (%)	96.0^{a}	97.4^{a}	93.4^{b}	84.0^{c}	p<0.01
Threonine (%)	96.5^{a}	97.5^{a}	91.6^{b}	82.0^{c}	p<0.01
Valine (%)	98.2^{a}	97.5^{a}	95.9^{b}	85.2^{c}	p<0.01
Methionine (%)	86.9^{b}	96.1^{a}	69.5^{c}	62.3^{d}	p<0.01
Cysteine (%)	89.7^{b}	96.3^{a}	97.4^{a}	87.8^{b}	p<0.01
Phenylalanine (%)	98.5^{a}	97.9^{a}	96.7^{a}	87.4^{b}	p<0.01
Tyrosine (%)	95.7^{a}	95.1^{a}	94.5^{a}	82.8^{b}	p<0.01

- Digestibility of **essential AA** of **Prosaf®** are very ↑ (> 95%) and **similar to that of FM**, except for Met and Cys which are reduced (but still good).
- Compared to **SBM, Prosaf®** is a **higher source** of **digestible Ile, Lys, Thr, Val, Met.**
- All **essential AA** are **much more digestible** in **Prosaf®** compared to **RSM**, except for Cys which has a comparable digestibility in both product.

2. YE inclusion in a low-FM formula: impact on feed intake

Trial design and methodology

- Whiteleg shrimp body weight: **13** ± 2 g
- Diets tested 2 by 2 in quadruplicates:
  - **High-FM formula (12% FM)**
  - **Low-FM formula (3% FM)**
  - **Low-FM + 2% Squid meal**
  - **Low-FM + 2% YE**
- 80 shrimp per tank (140 shrimp/m^2)
- Equal amounts of feed distributed at each meal
- 2 meals per day, during 15 days
- 1h after each meal: leftovers weighted (DW) for feed intake calculation
- The position of the feeding trays changed daily


© Alberto Nunes, Professor at Labomar-UFC, Brazil.

High-FM and Low-FM formulas were formulated with SBM and SPC to be isonitrogenous (CP: 35%) and isoenergetic, with balanced AA profiles

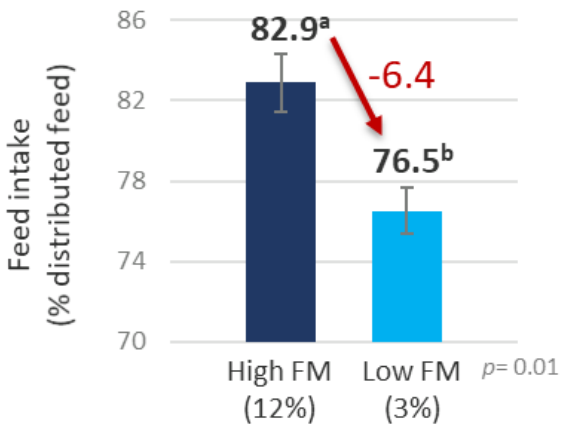
2. Dietary formulas

%	CTRL HighFM	CTRL LowFM	CTRL LowFM + 2% test ingr.
Soybean meal	42.24	43.5	98.0
Wheat flour	25.0	25.0	
Fishmeal (salmon)	12.0	3.0	
Wheat gluten	3.45	4.4	
Soy protein concentrate	2.0	9.0	
Fish oil (salmon)	3.0	2.7	
Soy lecithin	2.98	3.4	
Calcium carbonate	1.64	1.6	
Monobicalcium phosphate	1.5	1.4	
Salt, common	1.35	1.3	
Potassium chloride	1.14	1.1	
Mineral vitamin premix	1.0	1.0	
Synthetic binder	0.5	0.5	
L-lysine	0.47	0.47	
DL-methione	0.19	0.26	
L-threonine	-	0.01	
Cholesterol	0.06	0.07	
Stay C, 35%	0.03	0.03	
Tested ingredients	-	-	2.0

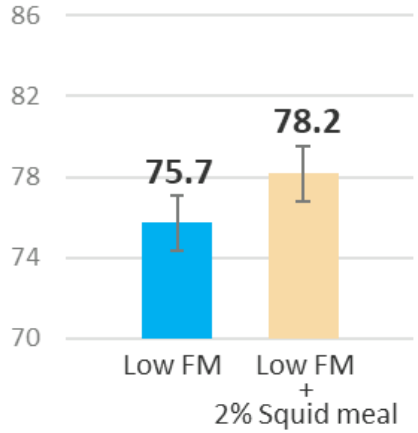
Sinking extruded pellets of 2.0 mm in diameter

2. Effect of Prosaf® on feed intake of a low-FM formula

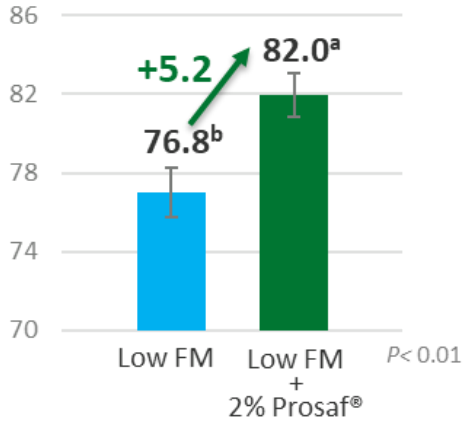
Global feed intake (FI) over a 15-days period



Shrimp prefer a high FM (12%) formula compared to a low FM (3%) one.



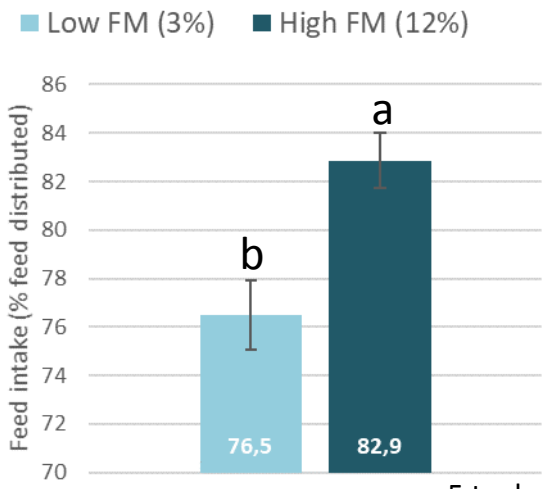
Inclusion of 2% squid meal in the low FM formula did not increase significantly FI.



Inclusion of **2% Prosaf®** in the **low FM formula** brought **attractiveness** and thus **increased FI**.

2. Low FM basal diet (3% FM) *vs* high FM basal diet (12% FM)

Global consumption over a 15 days period



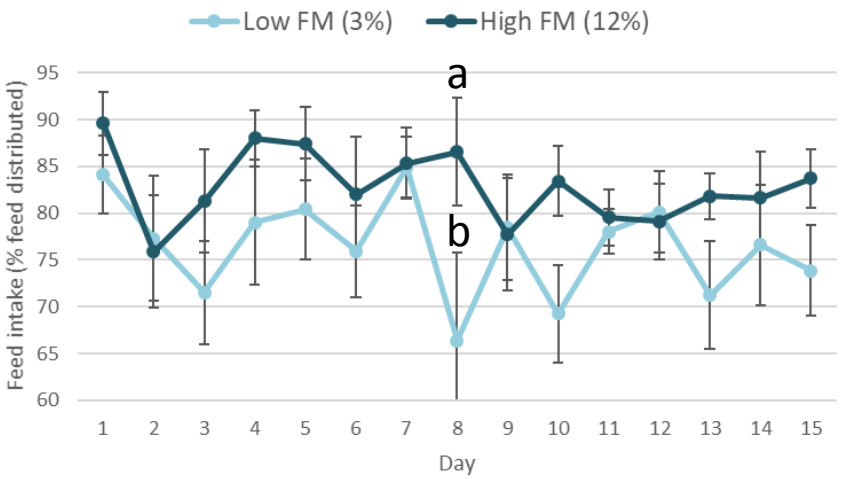
Paired Student's *t*-test, *p*= 0.01 n=5 tanks

Per day: average of the consumption of 5 tanks, twice a day

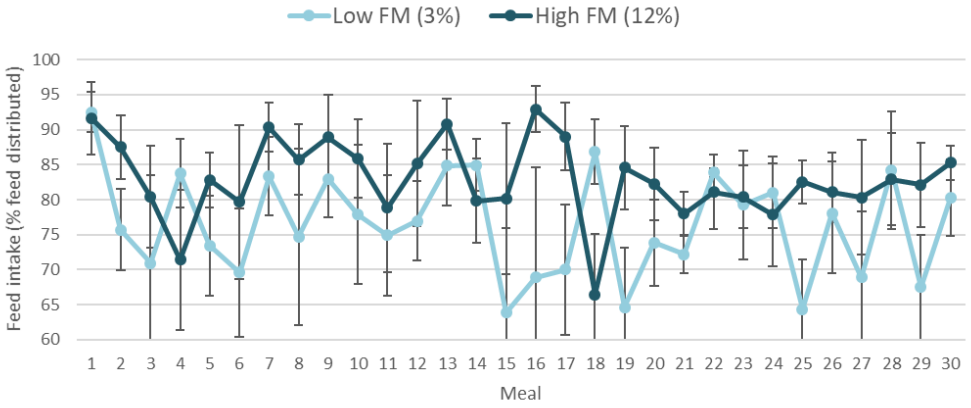
Per meal: average of the consumption of 5 tanks

High FM diet had higher consumption over 80% of the daily feeding period and 76.7% of the meals

Consumption per day over a 15 days period

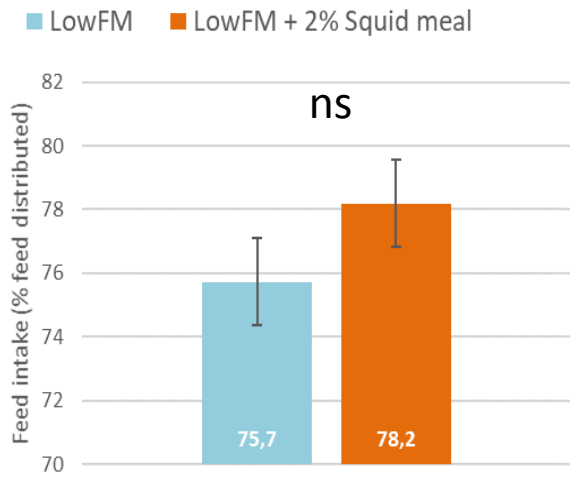


Consumption per meal over a 15 days period



2. Low FM diet *vs* 2% Squid meal in Low FM diet

Global consumption over a 15 days period



Paired Student's *t*-test, *p*=0.14

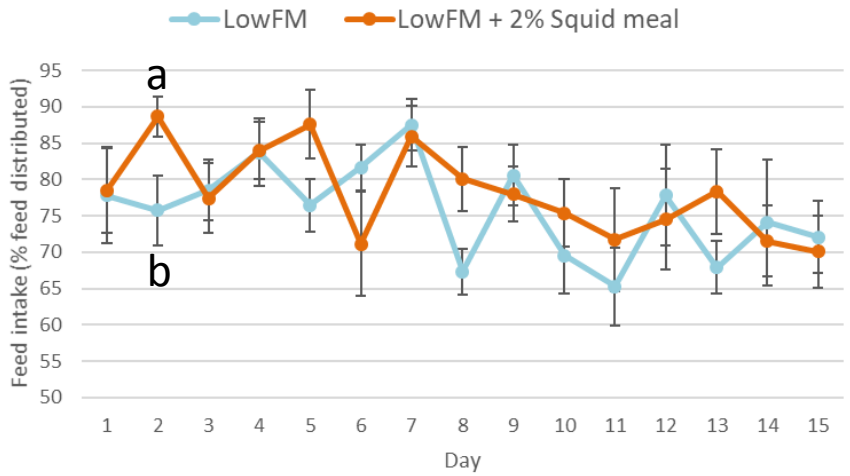
n=4 tanks

Per day: average of the consumption of 4 tanks, twice a day

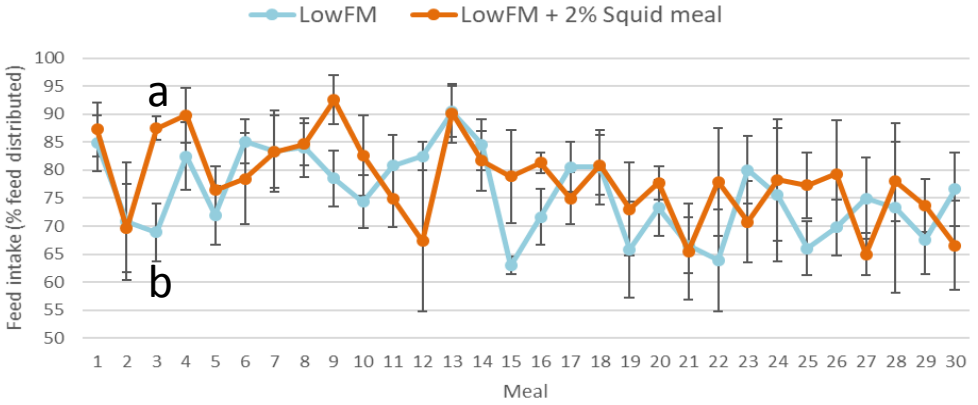
Per meal: average of the consumption of 4 tanks

Low FM +2% Squid diet had higher consumption over 53.3% of the daily feeding period and 60.0% of the meals

Consumption per day over a 15 days period

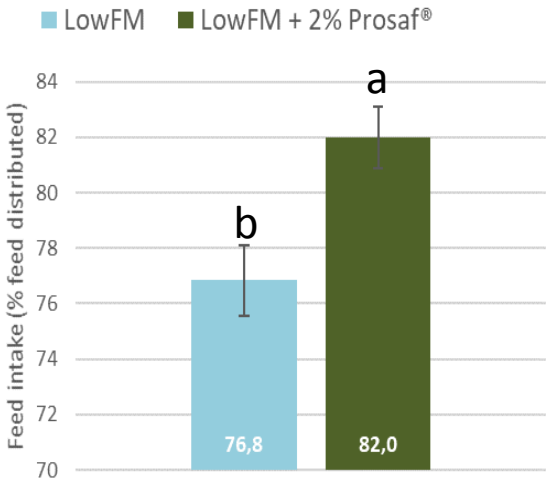


Consumption per meal over a 15 days period



2. Low FM diet *vs* 2% Prosaf® in Low FM diet

Global consumption over a 15 days period



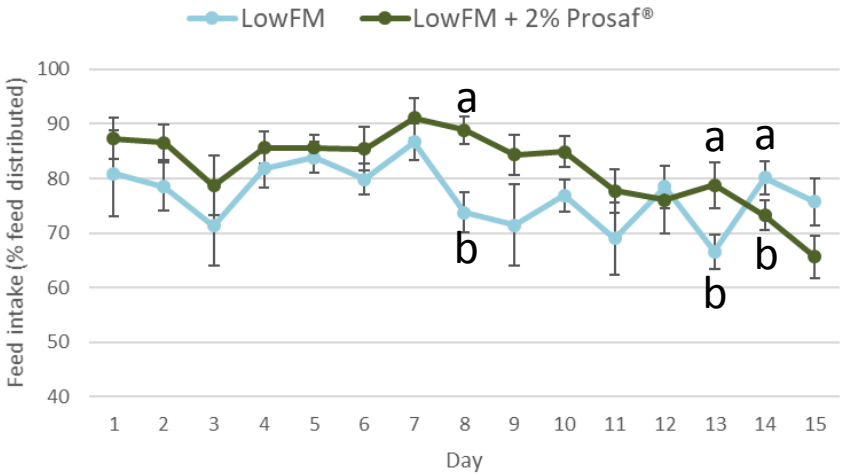
Paired Student's *t*-test, *p*= 0.0005 n=5 tanks

Per day: average of the consumption of 5 tanks, twice a day

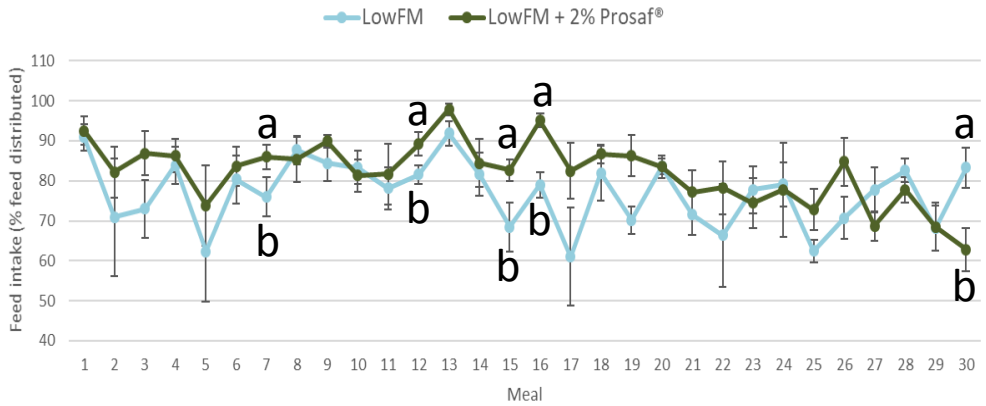
Per meal: average of the consumption of 5 tanks

Low FM +2% PROSAF diet had higher consumption over 80.0% of the daily feeding period and 76.7% of the meals

Consumption per day over a 15 days period



Consumption per meal over a 15 days period



3. Prosaf® inclusion in a low-FM formula: impact on growth, digestibility and immune status

- **Trial design and methodology :**

❖ **Diets tested**:

- **High-FM formula (15% FM)**
- **Low-FM formula (5% FM)**
- **Low-FM + 0.5% YE**
- **Low-FM + 1.5% YE**
- **Low-FM + 2.5% YE**

❖ Initial body weight

❖ 4 tanks per condition, 20 juveniles per tank (200L tanks)

❖ Duration: 62 days = **9 weeks**

❖ Shrimp fed 4 times per day to apparent satiation

❖ Measurements:

- Growth & zootechny monitoring
- Dietary nutrient digestibility
- Immune status indicators

Formulas were formulated with SPC to be isonitrogenous (CP: 36%) and isolipidic (8%), with balanced AA profiles

3. YE inclusion in a low-FM formula: impact on growth, digestibility and immune status

%	PC (15% FM)	NC (5% FM)	0.5% Prosaf	1.5% Prosaf	2.5% Prosaf
Fishmeal	**15.0**	**5.0**	**5.0**	**5.0**	**5.0**
Dehulled soybean meal	32.0	32.0	32.0	32.0	32.0
Soy Protein Concentrate	**4.9**	**15.5**	**14.9**	**13.6**	**12.3**
Wheat gluten	**4.5**	**4.5**	**4.5**	**4.5**	**4.5**
Squid meal	**3.0**	**3.0**	**3.0**	**3.0**	**3.0**
Wheat flour	22.0	22.0	22.0	22.0	22.0
Fish oil	3.91	4.52	4.53	4.55	4.55
Lecithin	2.0	2.0	2.0	2.0	2.0
Vitamin-mineral premix	1.9	1.9	1.9	1.9	1.9
Choline chloride	0.5	0.5	0.5	0.5	0.5
Cholesterol	0.35	0.35	0.35	0.35	0.35
KCl	2.45	2.45	2.45	2.45	2.45
Mg oxide	1.6	1.6	1.6	1.6	1.6
CaCO3	1.7	1.7	1.7	1.7	1.7
Ground rice hull	3.95	2.55	2.64	2.93	3.23
DL-methionine	0.24	0.43	0.43	0.42	0.42
Prosaf®632	-	-	**0.50**	**1.50**	**2.50**

3. Growth performance after 62 days

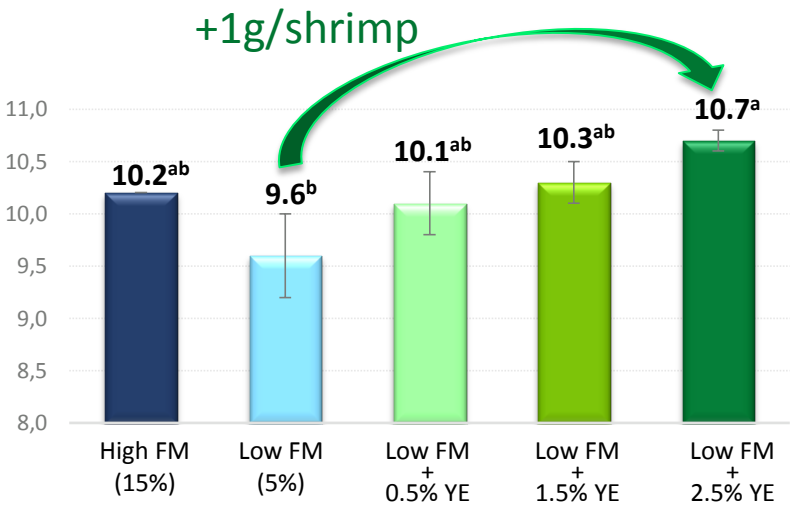
Group	Final body weight (g/shrimp)	Weight gain (g/shrimp)	Average daily growth (g/day/shrimp)	Specific growth rate (%/day/shrimp)	Survival (%)
PC (15% FM)	10.2 ± 0.0 ab	9.1 ± 0.0 ab	0.15 ± 0.0 ns	3.66 ± 0.01 ab	82.5 ± 1.4 a
NC (5% FM)	9.6 ± 0.4 b	8.5 ± 0.3 b	0.14 ± 0.0	3.57 ± 0.04 b	76.0 ± 1.0 b
0.5% Prosaf	10.1 ± 0.3 ab	9.1 ± 0.3 ab	0.15 ± 0.0	3.67 ± 0.04 ab	82.5 ± 1.4 a
1.5% Prosaf	10.3 ± 0.2 ab	9.2 ± 0.2 ab	0.15 ± 0.0	3.69 ± 0.04 ab	77.5 ± 1.4 b
2.5% Prosaf	10.7 ± 0.1 a	9.6 ± 0.1 a	0.15 ± 0.0	3.75 ± 0.01 a	80.0 ± 0.0 ab

- After 62 days of feeding, shrimp fed the low FM formula displayed a lower FBW, WG and SGR compared to shrimp fed the high FM formula.
- Addition of increasing levels of Prosaf in the low FM formula allowed to **improve growth performance of shrimp (FBW, WG, SGR)**, those improvement being statistically significant for **2.5% Prosaf** addition.

3. YE inclusion in a low-FM formula: impact on growth

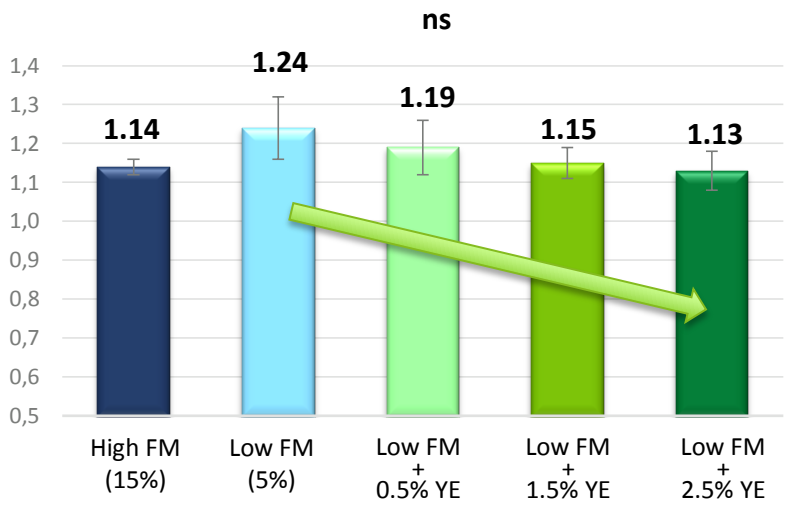
- **Growth performance and zootechny after 9 weeks of feeding**

Final body weight



Statistical analyses: ANOVA + Tukey test, $P<0.05$

FCR



➢ **Adding YE allowed to mitigate the negative impact of decreasing FM level on growth and those effects were significantly counteracted with 2.5% YE**

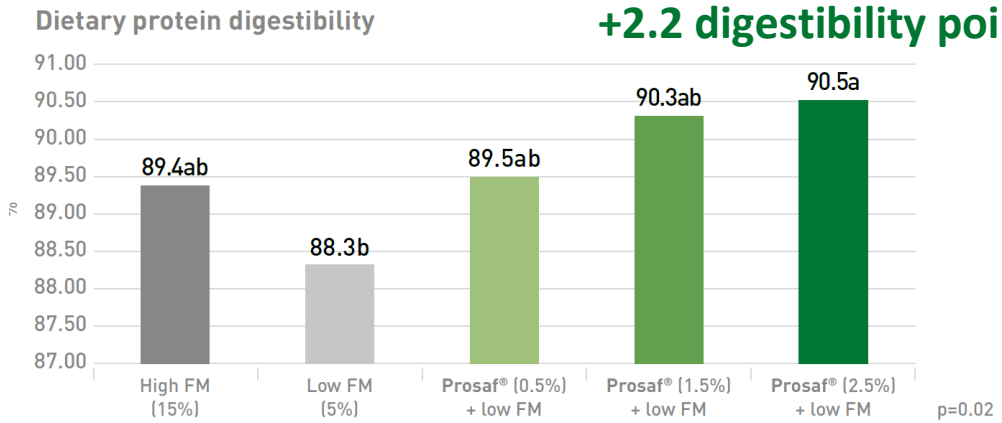
3. YE inclusion in a low-FM formula: impact on digestibility

- **<u>Apparent digestibility coefficient (ADC) of feed nutrients and energy:</u>**

Indirect method, 0.5% chromic oxide included in the diets.

	High FM (15% FM)	Low FM (5% FM)	Low FM + 0.5% YE	Low FM + 1.5% YE	Low FM + 2.5% YE	
Dry matter	74.0 ± 0.6	73.7 ± 0.6	73.4 ± 0.8	72.7 ± 1.5	72.3 ± 0.4	
Protein	89.4 ± 0.3^{ab}	88.3 ± 0.5^{b}	89.5 ± 0.8^{ab}	90.3 ± 0.3^{ab}	90.5 ± 0.2^{a}	*P*<0.05
Energy	82.5 ± 0.8^{a}	80.7 ± [illegible]0^{ab}	80.8 ± 0.9^{ab}	80.1 ± 1.8^{b}	80.5 ± 1.0^{ab}	*P*<0.05

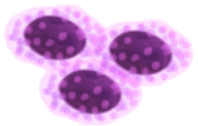
Statistical analyses: ANOVA + Tukey test

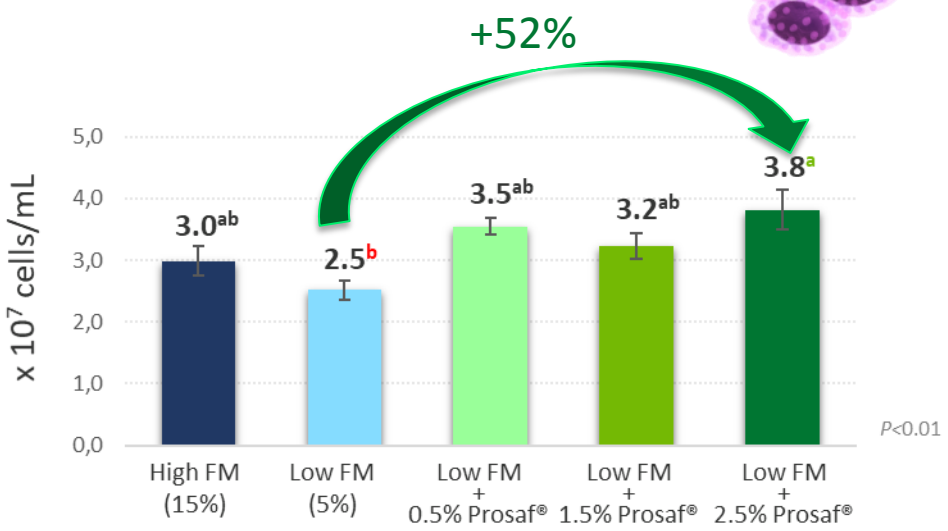


➢ **Adding 2.5% YE improved digestibility of dietary crude protein of the low-FM formula**

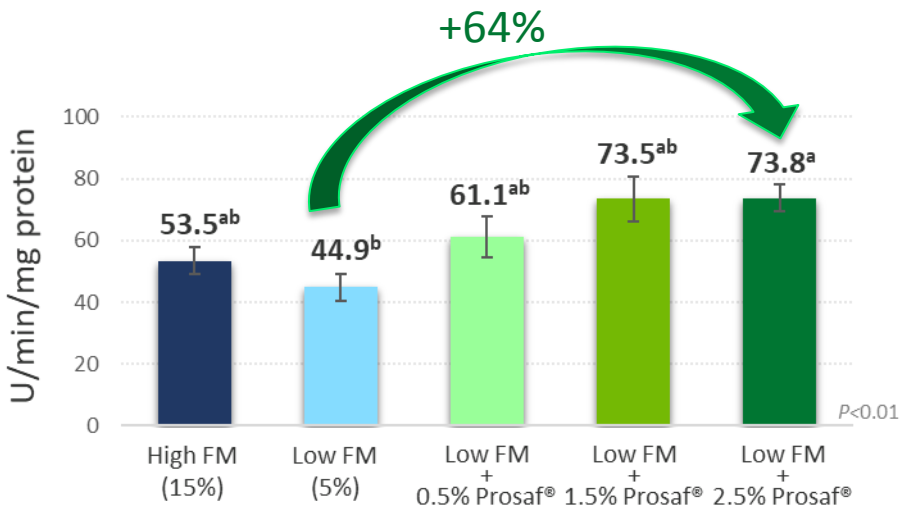
3. Inclusion of Prosaf® in a low-FM formula: impact on immune status

Total haemocyte count





Phenoloxidase activity



- Shrimp fed with a low FM formula tended to display a ↓ haemocytes count and a ↓ phenoloxydase activity compared to the high FM formula.
- Adding **Prosaf®**in the low-FM lead to an ↑ **in total haemocyte count** and **phenoloxydase activity. 2.5% of Prosaf was significant higher**.
- Results suggest a **better immune status** for shrimp fed Prosaf®-supplemented low-FM formula.

Conclusion

Prosaf®

A highly digestible source of:

- ✓ **Proteins**
- ✓ **Essential amino acids**
- ✓ **Energy**

✓ **Its inclusion in a very low-FM formula**

- ▪ **Brings attractiveness and increase shrimp feed intake**
- ▪ **Improves growth performance of shrimp**
- ▪ **Improves feed digestibility**
- ▪ **Improves shrimp immune status**

✓ **Feasible tool to increase sustainability in shrimp nutrition**

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