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YEAST - SUSTAINABLE NUTRIENT SOURCE FOR FISH FEED - REVIEW

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Abstract

Traditionally, when growing fish, their protein and fat requirements are provided by fishmeal, fish oil, soybeans, etc. More recently, to protect biodiversity and the environment, but also to use sustainable natural resources, researchers in the field are looking for alternative ingredients that can meet the requirements of fish feed. Utilizing the nutritional potential of yeast strains creates sustainable opportunities for new sources of high-quality protein. Thus, the use of yeasts is a solution to improve the economic profitability of aquaculture, as well as to reduce the impact on the environment. This paper focuses on those studies and scientific findings on the use of yeast biomass as a source of quality protein as an alternative to fishmeal and fish oil, as well as soy derivatives in fish feed. Studies have shown that the yeast biomass used in fish feed in various rations has been shown to improve immunity, resistance to bacterial infections, and increase growth rate.

Key words: *yeast, fish feed, aquaculture, sustainable.*

INTRODUCTION

The current trend of human consumption has undergone a huge increase in line with population growth and high living standards. Also, the latest technological advances have increased the accessibility of the population to a wide variety of foods and processed products from all over the world. This also brings disadvantages due to the negative effect brought by the ever-expanding food chain (large transport routes with huge quantities of food to be transported by water, road and air). Thus, the need to shorten the food chain and increase the accessibility of local products is more than obvious. At the same time, due to climate change, the processes of obtaining food must be aligned with the legislative requirements in force at the moment and with the trend imposed by the circular economy promoted by the European Union. The circular economy is a model of production and consumption that involves sharing, reusing, repairing, renovating and recycling existing materials and products as much as possible. In this way, the life cycle of the products is extended. In practice, this involves minimizing waste. When a product reaches the end of its life, the materials from which it is made are kept in the economy whenever possible. They can be used again and again, thus creating additional value.

The coming years will bring great challenges in terms of feeding the growing population with the least possible impact on the environment, especially for areas where major environmental changes are expected - areas prone to drought, forest fires, floods or landslides (FAO, 2017; Suweis, S. et al., 2015; United Nations, 2018).

Yeast is a eukaryotic organism with high nutritional value, which makes it suitable for animal feed (Shurson G.C., 2018).

The manufacturing process of many products depends on the processes triggered and supported by microorganisms. Wine, beer, and bread are just a few examples of yeast-dependent products (Rocio G-P et al., 2011). Studies on the possibility of using bacteria, fungi and algae have been conducted since 1996. Following these studies, quality protein was obtained from microbial sources and was named "Single Cell Protein" - SCP (Anamika Malav et al., 2017). Globally, a total production of approximately 0.4 million metric tons of yeast biomass is estimated, half of which is from the bakery industry (Rocio Gomez-Pastor, 2011).

Yeasts have a beneficial effect on health due to their vitamin content (especially in group B), and have a role in the production of microbial proteins, β-glucans and mannans. Also, due to their high protein content and probiotic properties, yeasts are an option in animal feed, especially if used yeast from different industries is used (Jach M.E. et al., 2015).

In nature, yeasts appear in the form of area-specific communities (in vineyards - wine yeasts; in barley fields appear yeasts that are used in the beer industry, etc.). Due to this fact, there are about 60 types of yeasts, with about 500 of different species, the differences being at the variation in cell morphology, metabolism of different substrates, and different reproduction (Lachance & Starmer, 1998; Stone, 2006).

In aquaculture, fish feed can represent over 50% of the operational cost. As the cost of feed remains high, finding quality feed at a reasonable price becomes a challenge for many commercial farmers. From the perspective of the impact on the aquatic environment, ways are being studied to reduce the number of fish needed for fishmeal and fish oil, as a food source for aquaculture, through feed alternatives such as biomass ingredients from yeast, microalgae or plants.

Sustainability concerns associated with the sources of protein and fishmeal currently in use and herbal flour have necessitated the search for new sustainable ingredients for use in aquatic food. Yeasts have been proposed as sustainable ingredients, mainly due to their potential to capitalize on non-food lignocellulosic biomass as valuable protein resources. Previously, there were extensive studies on the role of yeast cell wall components in modulating fish health responses. However, research on its use as a major source of protein in fish diets is still in its infancy. Yeast cells contain appreciable crude protein (approximately 40-55%) and other bioactive components beneficial to fish growth and development *(*Øverland M. et al., 2013; Hansen et al., 2019; Rawling et al., 2019; Vidakovic et al., 2020).

Yeats have been proposed as sustainable ingredients, especially for their potential to capitalize on non-food lignocellulosic biomass in protein resources. Studies on the role of yeast cell wall components in modulating fish health responses have been performed, however, further research on its use as a major source of protein in fish diets is needed.

MATERIALS AND METHODS

To accomplish this article, a literature review was conducted to investigate new research studies that have been conducted in recent years on the possibility of integrating residual yeast into fish feed. The content analysis of the revised studies aimed at defining the scope of the analysis, the evaluation of the content, in order to finally classify the content in order to highlight the shortcomings in this field and to give a direction for future research. In order to obtain the necessary information, research articles and reviews on topics such as "fish feed with added yeast" and "fish grow rate" were targeted. The databases used were: Web of science, Elsevier, Springer, Scopus and Google Scholar, etc.

RESULTS AND DISCUSSIONS

Studies have been performed on several yeast species (*Saccharomyces cerevisiae, Cyberlindnera jadinii, Kluyveromyces marxianus, Blastobotrys adeninivorans* and *Wickerhamomyces anomalus*, etc.) to determine their protein quality in order to replace fishmeal and soybean meal. It is true that the crude protein content of yeast (40-55%) is lower than that of fishmeal, but it is comparable to soybean meal. It is also known that, compared to fishmeal, there are species of yeasts with amino acid profiles that are limiting factors for different species of fish, such as Atlantic salmon and rainbow trout (Agboola O.J., 2020).

Studies on the replacement of fish feed elements with yeast have been performed. Thus, in 2019 Jingping Guo et al. studied the effect of using a yeast instead of fishmeal and soy flour in shrimp. Different food chains were used in which fishmeal and soy were replaced with yeast in different quantities. It was found that, compared to batches of shrimp fed with conventional feed, batches fed with feed with added yeast showed similar or better values in terms of final biomass, survival, protein retention efficiency and feed conversion ratio. Thus, the results indicated that 180-240 g of yeast/kg of feed can be used effectively in shrimp diets as a substitute for fishmeal or up to 240 g of yeast/kg of feed when replacing soybean meal (Guo J., 2019).

Another study was conducted by A. Estévez et al. in 2021. They performed two experiments to test the effect of partially replacing fishmeal with two by-products from the brewing, yeast and waste grain industry, included in the isoprotein and isolipid diets for gold rush (*Sparus aurata*). They concluded that the addition of up to 30% brewers' spent yeast and 15% spent grain in the feed for fish gave similar results in terms of growth, food conversion and fillet final composition to a feed with fish meal as the main protein source and show a protein digestibility of 89-95%.

In 2020, Hardy Joël Timothée Andriamialinirina et al. studied the effect of yeast hydrolyzate addition on growth, hematology, antioxidant enzyme activities and non-specific immunity of juvenile Nile tilapia (*Oreochromis niloticus)*. They had 3 experiments in which they fed the fish, twice a day, with 3 food recipes (control, with 1% and 3% addition of yeast hydrolysate) during 8 weeks. Their results showed no significant difference in survival among all treatments. The fish fed 1% and 3% yeast hydrolyzate had significantly higher glutathione peroxidase, superoxide dismutase, catalase activity and a significantly lower malondialdehyde level in the liver than the control group, indicating enhancement of the anti-oxidant status.

In 2018, Reda M. R. et al. studied the effect of yeast nucleotide addition on antioxidant activity, non-specific immunity, intestinal cytokines, and disease resistance in Nile Tilapia. They fed the fish with 4 types of food (control, addition of 0.05%, 0.15% and 0.25% yeast nucleotides). From the actual determinations, significantly higher serum protein, albumin, total serum globulin, total WBC counts, and lymphocyte and granulocyte contents were observed in the feed with the addition of yeast nucleotides compared to the control feed. Regarding the survival rate upon exposure to sober Aeromonas, the fish in the fodder groups fed with the addition of yeast nucleotides the percentage of survivals was significantly higher than in the control group. They concluded that the administration of feed with 0.25% addition of yeast nucleotide improved blood proteins, leukocytes, antioxidant activity, non-specific immunity, cytokine gene expression, and disease resistance of Nile Tilapia.

Rosale et al., (2017) in a study of *Sciaenops ocellatus* red road fish, evaluated the effectiveness of dry yeast with different amounts of yeast in feed distributed differently (20-50%) as a partial substitute for fishmeal. After eight weeks, they concluded based on the results obtained that the dry yeast could replace up to 30% and 50% of the fishmeal protein, respectively, and at the end of the test period there were no negative effects on the fish growth performance.

Omar et al., in 2012, tried to highlight the benefits of using a product that contains wheat as a raw material and yeast in different concentrations for protein intake, for mirror carp fish carp *Cyprinus carpio*. At the end of the test period, the yeast-fed fish developed better than the control-fed fish, and no microbial analysis showed any changes between the two variants.

Replacing/supplementing a fraction of fish feed with yeast is a topic that has begun to gain increasing interest. Thus, the growth performance fish on different diets containing some levels of yeast from research trials recent is presented in Table 1.

To determine the effects of adding yeast hydrolyzate, Xiang-Yang et al. conducted a study in 2017 that looked at the growth performance and resistance to stress of juvenile carp Jian (*Cyprinus carpio* var. *Jian*). The researchers formed three variants: one control, one with food with the addition of 3% and 5% hydrolyzed yeast. The fish of the 3 variants were fed for 10 weeks. After the feeding period, it was observed that the addition of yeast hydrolyzate positively influenced weight gain and immunity, the highest values of weight gain were observed in the version with the addition of 3% yeast hydrolyzate than fish fed without yeast. Also, higher values were observed in the protein and albumin content of the fish fed with 3% hydrolyzed yeast compared to the control group. The observations of this study suggest a positive contribution of the addition of yeast hydrolyzate on growth performance and immunity (Xiang-Yang et al., 2017).

A larger study was performed on the Nile tilapia, *Oreochromis niloticus*. The effects of different ratios of brewer's yeast additives, *Saccharomyces cerevisiae*, on growth performance, body composition and nutrient utilization were investigated. The fish were fed for 51 days, with food with different yeast content (0%, 10%, 15%, 20%, 30% or 40%) instead of fishmeal. The results showed that the body weight tripled for the fed fish up to 20% yeast incorporation. Fish fed with 40% yeast showed lower values, the best option for fish feed was the one with the addition of 15% yeast to promote the growth and efficient use of the diet, without negative effect (Ozório et al., 2012).

Table 1. Effect of different diets containing some levels of yeast on fish growth performance

Yeast	Yeast supplemented (%)	Crude protein (%)	Crude lipid (%)	Ash (%)	Daily growth coefficent (% day^{-1})	References
Saccharomyces cerevisiae	0÷5	34.37÷37.78	5.21÷5.39	7.26÷7.52	1.9÷3.75	Xiang et al., 2017
Saccharomyces cerevisiae	0÷40	26.3÷27.4	10.3÷11.9	8.5÷10.2	1.02÷2.08	Ozório et al., 2012
Saccharomyces cerevisiae	0÷100	34.5÷37.07	3.48÷6.2	9.36÷9.89	1.81÷5.64	Solomon et al., 2017
Saccharomyces cerevisiae + Wickerhamomyces anomalus	40÷60	46÷53	1÷6	5÷10	1.1÷1.3	Huyben, 2017
Saccharomyces cerevisiae	0÷2	31÷31.18	-	8.72÷8.86	3.75÷5.16	Essa et al., 2011
Saccharomyces cerevisiae	0÷45	37.31÷37.49	7.92÷7.99	2.93÷3.44	3.08÷4.96	Gumus et al., 2016
Saccharomyces cerevisiae	0÷15	30.28÷31.13	7.55÷7.98	10.46÷11.56	1.08÷2.23	Banu et al., 2020
Saccharomyces cerevisiae	0÷24	37.46÷38.92	8.3÷8.6	6.1÷7.4	3.5÷4.5	Guo et al., 2019
Saccharomyces cerevisiae	20÷50	41.5÷43.1	11.4÷13.0	7.9÷9.9	-	Rosale et al., 2017
Saccharomyces cerevisiae	7.5÷50	35.21÷35.82	6.47÷7.20	9.05÷10.60	2.21÷2.46	Omar et al., 2012

The performance of African catfish *Clarias gariepinus* with dry brewer's yeast food was tested by five diets of increasing soybean meal replacement with 25%, 50%, 75% and 100% dry brewer's yeast and a control without dry brewer's yeast. After 8 weeks of testing, it was found that the protein efficiency ratio and the specific growth rate differed significantly between the groups tested, the specific growth rate decreased with increasing substitution, while the efficiency and utilization of the protein decreased with increasing levels of protein yeast. They concluded that the optimal range of inclusion and replacement of soy flour with brewer's yeast in *C. gariepinus* feed is between 1% and 14% of the dry matter (Solomon et al., 2017).

In a 214-day experiment on the African, Egyptean and hibrid between these catfish *Clarias gariepinus* fed a diet containing about 31% crude protein, they were tested with four diets with dry brewer's yeast, *Saccharomyces cerevisiae*, at levels of 0.0, 1, 0, 1.5 and 2.0%. The results show that the diet with 2% yeast had the highest final body weight, with a growth rate (4.72 g/fish/day), also, demonstrated the benefits of using brewer's yeast as feed additives in hybrid African catfish diets (Essa et al., 2011).

A feeding study was carried out to examine the potential of replacing fish meal with brewer's yeast in the diet of goldfish (*Carassius auratus*). 5 diets were tested, in which the protein from fish meal was replaced with 0%, 15%, 25%, 35% and 45% of yeast, for 84 days. At the end of the experiment, according to results obtained, the weight growth of the fish fed the diet in which the fish meal was replaced by 35% yeast was better than that of the fish fed the other diets. However, the addition of brewer's yeast over 35% of fish meal, this replacement has led to a slight decrease in the growth performance of goldfish (Gumus et al., 2016).

Rubia Banu et al. (2020) studied the effects of baking yeast as an additive in animal feed, to evaluate the growth performance, feed use and disease resistance to freshwater catfish *Mystus* *cavasius.* The fish were fed an experimental recipe containing 0.5 to 1.5 g of yeast/kg of food for 75 days. The results indicated that the yeast supplement is a promoter, with a role in improving feed intake, with a promising increase and could be an alternative method to antibiotics for the prevention of *M. cavasius* disease. In addition, significantly higher amounts of crude protein and carbohydrates were obtained, and the feed conversion ratio was also significantly improved in yeast-fed fish.

Yeast is a protein alternative for farmed fish, replacing fish meal without producing major effects on their development. Fish meal has been replaced in different percentages by the yeasts *Saccharomyces cerevisiae* and *Wickerhamomyces anomalus*. Following the study to observe the effects of feeding different species of fish, with different amounts of yeast, it was concluded that the use of yeast can successfully replace between 40 and 60% protein in fish meal, without reducing the growth performance of fish (Huyben D., 2017).

To assess the effects of brewer's yeast, two growth trials were conducted of Pacific white shrimp post larvae and nursed inan indoor recirculating system using diets were different brewer's yeast levels (0, 6, 12, 18, 24%) to replace fish meal and soy flour, in practical shrimp feed. Results indicate that at least 18% yeast can be used to replace fishmeal without reduced growth performance. The results showed that shrimp fed the 0% diet had a significantly higher average final weight and weight gain than those offered with the 24% diet and indicated that 18-24% yeast can be used effectively in diets with shrimp as a replacement for fish meal (Guo et al., 2019).

CONCLUSIONS

The stage of knowledge in the use of yeast in animal feed is increasing. It is obvious that the use of yeast (especially spent yeast) in animal feed is a win-win situation. Globally, there are record productions of spent yeast, which would have a place in fish feed with positive effects on the environment: used yeast will gain added value, it will no longer pollute the environment, and fish are no longer used in the manufacture of fishmeal so necessary in their food. If we also turn our attention to the huge demand for fish products (especially culture products) it is obvious that yeast has its place in fish food.

One of the ultimate goals of protein nutrition is formulation of high quality and yet cost-effective feed with efficient utilization of alternative protein sources.

This review also presents future area of research and emphasize the need for large-scale production of yeast at competitive price to constitute a feasible replacement for fishmeal and soy protein in aquaculture.

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REFERENCES

Agboola, J.O., Øverland, M., Skrede, A., & Hansen, J.Ø. (2020). Yeast as major proteinrich ingredient in Aquafeeds: A review of the implications for aquaculture production. *Reviews in Aquaculture*, *13*(2), pp.949–970. https://doi.org/10.1111/raq.12507

Banu, M.R., Akter, S., Islam, M.R., Mondol, M.N., & Hossain, M.A. (2020). Probiotic yeast enhanced growth performance and disease resistance in Freshwater Catfish Gulsa Tengra, Mystus Cavasius. *Aquaculture Reports*, *16*, 100237. https://doi.org/10.1016/j.aqrep.2019.100237

Effects of feeding yeasts on blood physiology and gut microbiota of ... (n.d.). Retrieved May 22, 2022, from https://www.researchgate.net/publication/319276232_Effects_of_feeding_yeasts_on_blood_physiology_and_gut_microbiota_of_rainbow_trout

Essa, M.A., Mabrouk, H.A., Mohamed, R.A., & Michael, F.R. (2011). Evaluating different additive levels of yeast, saccharomyces cerevisiae, on the growth and production performances of a hybrid of two populations of Egyptian African catfish, Clarias gariepinus. *Aquaculture*, *320*(1-2), pp. 137–141. https://doi.org/10.1016/j.aquaculture.2011.08.015

Estévez, A., Padrell, L., Iñarra, B., Orive, M., & Martin, D.S. (2021). Brewery by-products (yeast and spent grain) as protein sources in Gilthead Seabream (sparus aurata) feeds. *Aquaculture*, *543*, 736921. https://doi.org/10.1016/j.aquaculture.2021.736921

Gause, B., & Trushenski, J. (2011). Replacement of fish meal with ethanol yeast in the diets of Sunshine Bass. *North American Journal of Aquaculture*, *73*(2), pp. 97–103.

Gomez-Pastor, R., Perez-Torrado, R., Garre, E., & Matall, E. (2011). Recent advances in yeast biomass production. *Biomass - Detection, Production and Usage*. https://doi.org/10.5772/19458

Growth and feed utilization of goldfish (Carassius auratus) fed graded ... (n.d.). Retrieved May 22, 2022, from https://www.researchgate.net/publication/305770363_Growth_and_feed_utilization_of_goldfish_Carassius_auratus_fed_graded_levels_of_brewers_yeast_Saccharomyces_cerevisiae

Guo, J., Qiu, X., Salze, G., & Davis, D.A. (2019). Use of high-protein brewer's yeast products in practical diets for the Pacific white shrimp *Litopenaeus vannamei*. *Aquaculture Nutrition*, *25*(3), pp. 680–690. https://doi.org/10.1111/anu.12889

Guo, J., Qiu, X., Salze, G., & Davis, D.A. (2019). Use of high protein brewer's yeast products in practical diets for the Pacific white shrimp *Litopenaeus vannamei*. *Aquaculture Nutrition*, *25*(3), pp. 680–690.

Jach, M. E., Serefko A., Sajnaga E., Kozak E., Poleszak E., Malm A. Dietary supplements based on the yeast biomass. Current topics in nutraceutical research 2015, 13(2), 83-88, ISSN 1540–7535. (10) (PDF) Dietary supplements based on the yeast biomass (researchgate.net) https://www.journalijdr.com/sites/default/files/issue-pdf/10488.pdf

Kurtzman, C. P., & Fell, J. W. (1998). *The yeasts, a taxonomic study*. Elsevier.

Malav, A., Meena, S., Dube, P., Sharma, M., & Sharma, M. (2017). *A critical review on singl cell protein production using different substrates*. Retrieved from https://www.journalijdr.com/critical-review-singl-cell-protein-production-using-different-substrates

Omar, S. S., Merrifield, D. L., Kühlwein, H., Williams, P. E. V., & Davies, S. J. (2012). Biofuel derived yeast protein concentrate (YPC) as a novel feed ingredient in carp diets. *Aquaculture*, *330-333*, pp. 54–62. https://doi.org/10.1016/j.aquaculture.2011.12.004

Øverland, M., Karlsson, A., Mydland, L.T., Romarheim, O.H., & Skrede, A. (2013). Evaluation of *Candida utilis, Kluyveromyces marxianus* and *Saccharomyces cerevisiae* yeasts as protein sources in diets for Atlantic salmon (*Salmo salar*). *Aquaculture*, *402-403*, pp. 1–7.

Øvrum Hansen, J., Hofossæter, M., Sahlmann, C., Ånestad, R., Reveco-Urzua, F. E., Press, C. M. L., Mydland, L. T., & Øverland, M. (2019). Effect of candida utilis on growth and intestinal health of Atlantic salmon (*Salmo salar*) Parr. *Aquaculture*, *511*, 734239. https://doi.org/10.1016/ j.aquaculture.2019.734239

Ozório, R. O. A., Portz, L., Borghesi, R., & Cyrino, J. E. P. (2012, January 13). *Effects of dietary yeast (Saccharomyces cerevisiae) supplementation in practical diets of tilapia (Oreochromis niloticus)*. Animals: an open access journal from MDPI. Retrieved May 22, 2022, from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4494266/

Rawling, M.D., Pontefract, N., Rodiles, A., Anagnostara, I., Leclercq, E., Schiavone, M., Castex, M., & Merrifield, D. L. (2019). The effect of feeding a novel multistrain yeast fraction on European seabass dicentrachus labrax intestinal health and growth performance. *Journal of the World Aquaculture Society*, *50*(6), pp. 1108–1122.

Reda, R. M., Selim, K. M., Mahmoud, R., & El-Araby, I. E. (2018). Effect of dietary yeast nucleotide on antioxidant activity, non-specific immunity, intestinal cytokines, and disease resistance in Nile tilapia. *Fish & Shellfish Immunology*, *80*, pp. 281–290. https://doi.org/10.1016/j.fsi.2018.06.016

Rosales, M., Castillo, S., Pohlenz, C., & Gatlin, D. M. (2017). Evaluation of dried yeast and threonine fermentation biomass as partial fish meal replacements in the diet of red drum Sciaenops ocellatus. *Animal Feed Science and Technology*, *232*, pp. 190–197. https://doi.org/10.1016/j.anifeedsci.2017.08.014

Shurson, G. C. (2018). Yeast and yeast derivatives in feed additives and ingredients: Sources, characteristics, animal responses, and quantification methods. *Animal Feed Science and Technology*, *235*, pp. 60–76. https://doi.org/10.1016/j.anifeedsci.2017.11.010

Solomon, S. G., Ataguba, G. A., & Itodo, G. E. (2017). Performance of *Clarias gariepinus* fed dried brewer's yeast *(Saccharomyces cerevisiae)* slurry in replacement for soybean meal. *Journal of Nutrition and Metabolism*, *2017*, pp. 1–8. https://doi.org/10.1155/2017/8936060

Stone, C. W. Yeast products in the feed industry: a practical guide for feed professionals. Yeast Products in the Feed Industry. 2006.

Suweis, S., Carr, J. A., Maritan, A., Rinaldo, A., & D'Odorico, P. (2015). Resilience and reactivity of Global Food Security. *Proceedings of the National Academy of Sciences*, *112*(22), pp. 6902–6907.

Future of Food and Agriculture – Trends and challenges. (n.d.). Retrieved 2022, from https://www.fao.org/3/i6583e/i6583e.pdf

Timothée Andriamialinirina, H. J., Irm, M., Taj, S., Lou, J. H., Jin, M., & Zhou, Q. (2020). The effects of dietary yeast hydrolysate on growth, hematology, antioxidant enzyme activities and non-specific immunity of juvenile Nile tilapia, *Oreochromis niloticus. Fish & Shellfish Immunology*, *101*, pp. 168–175. https://doi.org/10.1016/j.fsi.2020.03.037

UN. The Sustainable Development Goals Report.United Nations, New York, 2018. pp. 40 https://unstats.un.org/sdgs/files/report/2018/TheSustainableDevelopmentGoalsReport2018-EN.pdf

Vidakovic, A., Huyben, D., Sundh, H., Nyman, A., Vielma, J., Passoth, V., Kiessling, A., & Lundh, T. (2019). Growth performance, nutrient digestibility and intestinal morphology of rainbow trout (*Oncorhynchus mykiss*) fed graded levels of the yeasts *Saccharomyces cerevisiae* and *Wickerhamomyces anomalus*. *Aquaculture Nutrition*, *26*(2), pp. 275–286. https://doi.org/10.1111/anu.12988

Yuan, X.-Y., Liu, W.-B., Liang, C., Sun, C.-X., Xue, Y.-F., Wan, Z.-D., & Jiang, G.-Z. (2017). Effects of partial replacement of fish meal by yeast hydrolysate on complement system and stress resistance in juvenile jian carp (*Cyprinus carpio* var. *Jian*). *Fish & Shellfish Immunology*, *67*, pp. 312–321.