Performance of *Clarias gariepinus* Fed Dried Brewer’s Yeast (*Saccharomyces cerevisiae*) Slurry in Replacement for Soybean Meal

Shola Gabriel Solomon, Gabriel Arome Ataguba, and Gabriel Enemona Itodo

*Department of Fisheries and Aquaculture, University of Agriculture, PMB 2373, Makurdi, Benue State 970001, Nigeria*

Correspondence should be addressed to Gabriel Arome Ataguba; gabynotepad@yahoo.co.uk

Received 9 July 2016; Revised 19 December 2016; Accepted 26 December 2016; Published 23 January 2017

Copyright © 2017 Shola Gabriel Solomon et al. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Following disparity of earlier results, this study tested the performance of African catfish *Clarias gariepinus* fed dried brewer’s yeast slurry meal (DBYM) based diets. Fingerlings of *C. gariepinus* with pooled mean initial weight of 1.58 ± 0.01 g were stocked in hapas (1 m × 1 m × 1 m) immersed in an earthen pond at a density of 15 fish per cage. Five diets with increasing substitution of soybean meal with 25%, 50%, 75%, and 100% of dried brewer’s yeast and a control without dried brewer’s yeast (0% substitution) were evaluated for 8 weeks. Palatability of diets reduced with increasing levels of DBYM. Growth and utilization parameters such as weight gain, feed conversion ratio, protein efficiency ratio, and specific growth rate differed significantly (*p* < 0.05) among treated groups. Specific growth rate decreased with increasing substitution while the best feed conversion ratio was obtained in the diet devoid of DBYM. Protein efficiency and utilization decreased with increasing levels of DBYM. Body composition was also affected by inclusion of DBYM with significant differences (*p* < 0.05) being observed across the diets. The trend in body composition follows the utilization of the diets. We conclude that the optimal range of inclusion and substitution of soybean meal with DBYM in *C. gariepinus* feed is between 1% and 14% of dry matter.

1. Introduction

Fish farming relies on feeds produced using ingredients such as soybean, fishmeal, corn meal, rice bran, fish oil, and other vegetable oils that are also highly demanded by terrestrial animal agriculture as well as human nutrition [1]. Feed quantity is a significant variable affecting fish farming [2] because feed accounts for over 50% of production costs [1, 3]. Hence feeds which can offer low FCR matched with species that can deliver low FCR will be beneficial. However, fish feed development in Sub-Saharan Africa has not made a significant progress as expected [4]. Fishmeal still remains the ingredient of choice in fish feeds because of its amino acid profile and acceptability by fish. According to [5], the nutritional value of a feed is determined by its digestibility and ease of assimilation while its quality depends on the growth of the animal as a result of consumption of the feed.

The aquaculture of *Clarias gariepinus* is growing steadily but farmers need to cut costs incurred on feed; hence the availability of cheap feed that meets the requirement of *C. gariepinus* would go a long way to increasing profitability. According to [6, 7], the development and expansion of aquaculture depend on availability of good quality and relatively inexpensive feed ingredients for the formulation of compounded feed.

Yeast slurry is usually recovered in the process of brewing and used for repitching but some slurry that is deemed unsuitable for repitching is moved into waste storage [8]. Brewer’s yeast (*Saccharomyces cerevisiae*) has been identified as an ingredient with several positive factors [9]. Brewer’s yeast slurry (*S. cerevisiae*) contains about 45% protein, 1% lipid, and 2.7% of crude fibre [10]. It has an excellent amino acid profile but its shortcoming lies in the deficiency of sulphur containing amino acids such as methionine and cystine with a high content of lysine [11]. Temperature plays an important role in the quality of the slurry. High temperatures tend to damage the viability of yeast for the beer industry [12] but this is not of significance in the animal feed industry.
as autolytic breakdown of yeast which occurs at 50°C can be optimized for extraction of protein and nitrogen contents [13].

Yeast has been used extensively in poultry and other animals as a growth promoter and also additive to enhance fibre utilization. The fermentation of feed dough by yeast has been utilized alongside local binders to produce local feed having greater water stability and floating, and it was discovered that cassava and corn flour produced pellets with greater water stability [14]. Yeast addition in broiler chicken diets has been reported to lower FCR [15] while [16] reported that yeast supplementation is ideal at the starter phase compared to the finisher phase of broiler production. According to [17], an inclusion level of 200 mg yeast per kg of diet for broilers resulted in better feed efficiency. Furthermore, [18] reported that rabbits fed a supplemental diet of cultured S. cerevisiae at 1.5 g/kg diet efficiently converted feed compared to rabbits fed unsupplemented feed and at a supplementation rate of 3.0 g/kg of diet, haematological parameters were greatly improved. Earlier problems of foaming in brewer’s yeast used for animal feed were overcome through a suggestion that fermentation in the beer industry is prolonged before cooling while rinsing with water was considered impracticable [19]. However, yeast washing is currently being used as a means of removing bacterial contamination from yeast [20].

Supplementation of fish feed with yeast has yielded mixed results with lower inclusion levels being favoured for most fish. A substitution level of 30% yeast has been advocated for Koi Carp [21] while 25% seems ideal for rainbow trout (Oncorhynchus mykiss) [22], cobia (Rachycentron canadum) [23], and Gilthead Sea Bream (Sparus aurata) [24]. Tilapia (Oreochromis niloticus) has been reported to utilize diets with 20% fishmeal substituted with brewer’s yeast effectively with higher percentages eliciting deleterious effects on growth [25]. The digestibility of spent yeast by catfish has been reported as 35% [26]. The African catfish has been reported to produce an FCR of 0.56 with an inclusion of 4% of graded baker’s yeast in the diet [27]. Furthermore, hybrid Clarias gariepinus have been reported to utilize diets with 2% level of dried brewer’s yeast effectively with the determination of optimal levels beyond 2% inclusion being open for further investigation [28]. However, substitution of soybean meal with bioactive yeast in the diet of the African catfish at 50% level has been reported without adverse effects [29]. The current level of inclusion of dried brewer’s yeast at 2% irrespective of soybean meal in the diet needs to be improved upon as suggested [28]. Previous reports on use of dried brewer’s yeast did not actually include the method of drying the slurry. This study therefore aims to show a drying method and determine the boundaries for the safe inclusion of dried brewer’s yeast while replacing soybean meal in the diet of the African catfish (C. gariepinus).

2. Materials and Methods

Clarias gariepinus fingerlings of average weight 1.58 ± 0.005 g were obtained from a fish farm at Makurdi Nigeria and transported to the University of Agriculture, Makurdi. The fish were acclimatized for two weeks and fed with a commercial diet. Feeding with this diet was stopped one day prior to the commencement of feeding using the yeast slurry based diets. Groups of 15 fingerlings of C. gariepinus were randomly weighed and stocked into fifteen different hapas (1 m × 1 m × 1 m) immersed in earthen ponds.

Brewer’s yeast slurry was obtained from Benue Breweries Makurdi and dried to a constant weight at 50°C in an oven. The yeast species is the top-fermenting type (Saccharomyces cerevisiae) with fermentation occurring at temperatures between 20 and 25°C. Fresh yeast slurry was obtained in batches from the brewery and transported in a plastic container of 10 litres capacity with ice packs surrounding it. Considering the flocculation ability of the yeast strain as seen from settling at the bottom of the transporting vessel, upon arrival at the laboratory, the liquid slurry was shaken gently by upside-down container flips to achieve homogeneity, centrifuged at 5000 rpm using a Centrikon T-324 centrifuge for 5 minutes; then the supernatant was discarded. The resulting solid residue was washed using cool (4°C) sterilized distilled water and quickly filtered using a suction filter with No. 1 filter paper. Solid residues were spread on sterilized, dried filter paper. Solid residues were washed using cool (4°C) sterilized distilled water and quickly filtered using a suction filter with No. 1 filter paper. Solid residues were spread on sterilized, dried filter paper. Solid residues were washed using cool (4°C) sterilized distilled water and quickly filtered using a suction filter with No. 1 filter paper. Solid residues were spread on sterilized, dried filter paper. Solid residues were spread on sterilized, dried filter paper. Solid residues were spread on sterilized, dried filter paper. Solid residues were spread on sterilized, dried filter paper.

Table 1: The proximate composition of brewer’s yeast slurry (Saccharomyces cerevisiae).

| Parameter | Brewer’s yeast meal [30] | Liquid brewer’s yeast [31] | Present analysis<sup>*</sup> |
|-----------|--------------------------|---------------------------|-----------------------------|
| Moisture  | 7.6                      | 85.6                      | 7.6 ± 0.15                  |
| Protein   | 46.1                     | 7.6                       | 45.9 ± 0.25                 |
| Lipid     | 1.3                      | 0.1                       | 1.7 ± 0.19                  |
| Ash       | 8.1                      | 1.4                       | 8.3 ± 0.12                  |
| Fibre     | 2.9                      | 0.7                       | 2.7 ± 0.06                  |
| NFE       | 34                       | 4.6                       | 33.8 ± 0.17                 |

<sup>*</sup><sub>𝑛 = 3</sub>
meal were varied from 0% to 100% hence: diet 1 [0%], diet 2 [25%], diet 3 [50%], diet 4 [75%], and diet 5 [100%]. Ingredient inclusion was determined on a dry matter basis and converted to weights as fed (Table 2). Amino acid requirements as obtained from literature were used to determine the chemical score for each amino acid in all five diets during formulation of the diets (Table 3). The diets were pelleted after weighing and mixing of the ingredients and dried to constant weight in an oven at 50°C for effective preservation.

Prior to the commencement of feeding, the proximate composition of fish carcass was determined using standard methods [35]. After feeding trials were stopped, proximate composition of test fish in all diets was also determined to understand the effect of feeding brewer’s yeast based diets on the body composition of the African catfish.

Water quality in each hapa was monitored weekly. Dissolved oxygen was checked using standard DO meter (Hana Instruments), pH was determined with a handheld pH meter, and temperature was taken with a mercury-in-glass thermometer. Secchi disc visibility was taken every week and used as an index of water turbidity. Mean water temperature was 27.6°C, mean dissolved oxygen was 5.32 mg·L⁻¹, pH averaged 7.9, and secchi disc visibility was 34.6 cm.

Gross energy values as well as the protein to energy ratio of each diet were determined after proximate composition of the diets was determined. Determination was done on the dry matter basis.

Each diet was fed to the catfish in triplicate hapas twice daily (09:00 hr, 16:00 hr) at 5% body weight for 56 days. Total fish weight in each hapa was determined every week and the amount of diet was adjusted accordingly. Growth response and feed utilization indices were estimated using various growth indices including weight gain, feed conversion ratio (FCR), specific growth rate (SGR), protein efficiency ratio (PER), and apparent net protein utilization (ANPU).

Data obtained was subjected to statistical analysis using Analysis of Variance (ANOVA) to determine if there were significant differences among the means and where differences occurred, means were separated using Fisher’s Least Square Differences (LSD). The nature of data for the final weight necessitated the use of Analysis of Covariance (ANCOVA) to determine if differences exist in the weight gain using final weight as covariate. Survival rates were arcsine transformed before analysis and retransformed to percentages after analysis.

3. Results

The proximate composition of the diets as determined is presented in Table 4. The moisture contents were below 12%.

Weekly weight increased for the experimental fish fed diets with varying inclusion levels of dried brewer’s yeast slurry meal (Figure 1). There was a uniform pattern of growth for all diets for the first week. Fish fed diet 1 increased in weight above the other treatments after week one and continued this trend until week eight. This was followed by fish fed diets 2 and 3. Fish fed diets 4 and 5 lagged behind those of diets 2 and 3 after the first week.

The growth performance and utilization of dried brewer’s yeast slurry by *Clarias gariepinus* are presented in Table 5. The mean weight gain was found to vary from 1.81 g (diet 5) to 3.64 g (diet 1) with fish fed diet 1 having the highest weight gain which differed significantly (p = 0.001) from all other diets. Similarly, the specific growth rate varied from 01.37% per day (diet 5) to 2.70% per day (diet 1). The Feed conversion ratio differed significantly (p = 0.000) among the treated fish. Feed conversion ratio increased with increasing levels of dried brewer’s yeast in the diets. Diet 1 produced the best FCR and diet 5 the worst. Protein use was more efficient from diet 1 and least efficient from diet 5. More protein from the feed was retained in the body by fish fed diet 2 while fish fed diet 5 retained the least protein from the feed. Feed intake by fish differed significantly (p = 0.003) with fish fed 100% soybean inclusion diet (diet 1) having the highest feed intake and fish fed the 100% inclusion of DBYM (diet 5) having the least feed intake and this also translates into the same pattern for protein intake which ranged from 2.55 g (diet 5) to 4.37 g (diet 1). Values for protein intake also differed significantly (p = 0.002).

The carcass composition of the experimental fish as presented in Table 6 shows that initial moisture level was similar across the diets but this varied significantly (p = 0.007) from the initial value in the fish prior to feeding with dried brewer’s yeast.

Crude protein content of fish flesh decreased with increasing substitution of dried brewer’s yeast with significant differences (p = 0.000) observed among treatments and in comparison to the initial value. Lipid content of fish flesh differed significantly among treatments and initial values. Ash content ranged from 3.09% (diet 2) to 3.32% (diet 5).
| Ingredient     | Diet 1 % dry matter | Diet 1 g/kg feed mix | Diet 2 % dry matter | Diet 2 g/kg feed mix | Diet 3 % dry matter | Diet 3 g/kg feed mix | Diet 4 % dry matter | Diet 4 g/kg feed mix | Diet 5 % dry matter | Diet 5 g/kg feed mix |
|----------------|---------------------|----------------------|---------------------|----------------------|---------------------|----------------------|---------------------|---------------------|---------------------|---------------------|
| Fish meal      | 11                  | 112.24               | 9.50                | 97.21                | 8.00                | 81.73                | 6.40                | 65.01                | 4.80                | 48.29               |
| SBM            | 57.8                | 562.99               | 43.35               | 417.11               | 28.90               | 273.55               | 14.45               | 134.02               | 0                   | 0.00                |
| BYS            | 0                   | 0                    | 14.45               | 144.02               | 28.90               | 273.55               | 43.35               | 428.92               | 57.8                | 566.43              |
| Corn meal      | 26.20               | 278.81               | 27.70               | 295.60               | 29.20               | 311.11               | 30.80               | 326.29               | 32.4                | 339.96              |
| Vit. premix    | 2.00                | 18.37                | 2.00                | 18.42                | 2.00                | 18.39                | 2.00                | 18.28                | 2                   | 18.11               |
| Min. premix    | 2.00                | 18.41                | 2.00                | 18.44                | 2.00                | 18.43                | 2.00                | 18.33                | 2                   | 18.15               |
| Salt           | 0.50                | 4.59                 | 0.50                | 4.61                 | 0.50                | 4.60                 | 0.50                | 4.57                 | 0.5                 | 4.53                |
| Oil            | 0.50                | 4.59                 | 0.50                | 4.61                 | 0.50                | 4.60                 | 0.50                | 4.57                 | 0.5                 | 4.53                |
**4. Discussion**

Increasing levels of dried brewer’s yeast slurry meal in the diet of *C. gariepinus* do not seem to support growth. Diet 1 with 0% DBYM in substitution for soybean meal produced the best specific growth rate as well as feed conversion efficiency. Reference [25] reported that the daily growth coefficient of tilapia reduced with increasing levels of yeast in substitution for fishmeal. Furthermore, [23] reported reduction of weight gain by cobia with increasing levels of yeast based protein in the diet. The rainbow trout (*Oncorhynchus mykiss*) does not also tolerate high levels of DBYM in its diet [22]. The inclusion of DBYM in the diet of *C. gariepinus* negatively affected SGR, FCR, and PER with a negative trend being observed.
beginning at 25% replacement of soybean with DBYM. According to [21], replacement of fishmeal at 40% level and above by DBYM in the diet of Koi Carp (Cyprinus carpio) led to reduced weight gain, SGR, PER, apparent digestibility, and increased FCR. At inclusion levels ranging from 0% to 2%, C. gariepinus has been reported to effectively utilize diets with FCR reducing as inclusion rate increased [28]. This therefore suggests that the substitution/inclusion rate range as used in FCR reducing as inclusion rate increased [28]. This therefore suggests that the substitution/inclusion rate range as used in the present study is wide and with the results, the range is narrowed to between 0 and 25% substitution for soybean meal.

Reduced palatability of the feed with increase in inclusion of DBYM was reflected in the growth response of C. gariepinus. Initial reduction of body protein with increasing inclusion level of DBYM was superior compared to the performance of diets occurred with higher inclusion levels (>25%) of DBYM. Substitution of soybean meal at 25% with DBYM still produced a chemical score of 100 for cystine; hence the performance of this inclusion is superior compared to the rest. Methionine is converted to cystine if there is a short supply of cystine in the diet [41]; hence the 40–60% methionine sparring ability of cystine [42, 43] is reversed and methionine deficiency occurs. Cysteine can provide about 50% of the needs of total sulphur amino acids in fish [44]. This can explain why there is poor protein efficiency but high protein conversion. Low level inclusion of yeast in the diet of C. gariepinus does not seem to affect protein metabolism as productive protein value or ANPU and PER were reported to increase with increasing levels (0%, 1%, 1.5%, and 2%) of yeast of the diet [28].

Whole body composition of C. gariepinus was affected by substituting yeast for soybean meal. However, a report by [45] shows that supplementing diets of hybrid striped bass have no significant effect on body composition. Similarly, [46] reported that the crude protein of rainbow trout flesh did not differ with increasing supplementation of yeast RNA extract. Reference [25] reported that the body composition of tilapia was affected by supplementing the diet with yeast; hence there was a reduction in body protein that was attributed to poor amino acid profile of the diets. Reference [23] presented a similar scenario to the one obtained for C. gariepinus here with differences being observed in muscle protein as substitution of fishmeal with yeast increased but substitution at 25% and total inclusion of fishmeal at 100% did not produce any significant effects on muscle protein. Similarly, [47] reported significant differences in the crude protein composition of M. rosenbergii postlarvae fed yeast supplemented diets. This similarity notwithstanding, the authors reported increasing crude protein levels in the flesh of the prawn with increasing yeast supplementation as against the declining trend observed for C. gariepinus. This clearly shows that prawns can tolerate yeast as a dietary ingredient.

On the whole, substitution of soybean meal with dried brewer's yeast meal in the diet of C. gariepinus between ~14.5 and 58% dry matter did not produce any significant advantages over the use of soybean at full inclusion. It is clear that

Table 6: Body composition of C. gariepinus fed diets containing various amounts of dried brewer's yeast substituted for soybean meal for 8 weeks.

| Parameters | Moisture | Protein | Lipid | Ash |
|-----------|---------|---------|-------|-----|
| Initial   | 75.60 ± 0.034 | 15.03 ± 0.004 | 6.21 ± 0.022b | 3.17 ± 0.022bc |
| Diet 1    | 74.45 ± 0.15b | 17.13 ± 0.02c | 5.31 ± 0.13c | 3.11 ± 0.044 |
| Diet 2    | 74.80 ± 0.10b | 17.11 ± 0.02c | 5.01 ± 0.09c | 3.09 ± 0.034 |
| Diet 3    | 74.75 ± 0.15b | 16.01 ± 0.03d | 6.02 ± 0.14b | 3.23 ± 0.02b |
| Diet 4    | 74.50 ± 0.20b | 15.86 ± 0.03c | 6.52 ± 0.25c | 3.12 ± 0.02c |
| Diet 5    | 74.73 ± 0.09b | 15.60 ± 0.01e | 6.36 ± 0.06ab | 3.32 ± 0.02c |

Means (±SEM, n = 3) in the same column with different superscripts differ significantly (p < 0.05).
substitution and inclusion levels for optimal performance are between 1% and 14% of dry matter.

Competing Interests
The authors declare that they have no competing interests.

References
[1] K. J. Rana, S. Siriwardena, and M. R. Hasan, Impact of Rising Feed Ingredient Prices on Aquafeeds and Aquaculture Production, Food and Agriculture Organization of the United Nations, Rome, Italy, 2009.

[2] A. Muhammad-Lawal and O. A. Omotesho, "Economic analysis of fish farming in the North central Nigeria: a case study of Kwara and Kogi states," Journal of Agricultural Research and Development, vol. 9, no. 1, pp. 21–36, 2010.

[3] D. M. Jamu and O. A. Ayinla, "Potential for the development of aquaculture in Africa," NAGA, vol. 26, no. 3, pp. 9–13, 2003.

[4] U. U. Gabriel, O. A. Akinrotimi, D. O. Bekibele, D. N. Onunkwo, and P. E. Anyanwu, "Locally produced fish feed: potentials for aquaculture development in sub-Saharan Africa," African Journal of Agricultural Research, vol. 2, no. 7, pp. 287–295, 2007.

[5] E. A. Akintunde, "Digestive enzymes in the digestive enzymes in the gut of Sarotherodon galilaeus (syn. Tilapia galilaeus, family cichlidae) of the Lake Kainji, Nigeria," Nigerian Journal of Science, vol. 18, pp. 22–25, 1985.

[6] N. Hishamunda and R. P. Subasinghe, Aquaculture Development in China: The Role of Public Sector Policies, Food and Agriculture Organization of the United Nations, Rome, Italy, 2003.

[7] A. G. Coche, B. A. Haight, and M. M. J. Vincke, Aquaculture Development and Research in Sub-Saharan Africa: Synthesis of National Reviews and Indicative Action Plan for Research, Food and Agriculture Organization of the United Nations, 1994.

[8] C. Boulton and D. Quain, Brewing Yeast and Fermentation, Blackwell, 2001.

[9] A. Paray and M. Mahmoudi, "Effect of different levels of supplemental yeast Saccharomyces cerevisiae) on performance, blood constituents and carcass characteristics of broiler chicks," African Journal of Agricultural Research, vol. 3, no. 12, pp. 835–842, 2008.

[10] P. Raven and G. Walker, Ingredients for Fish Feed Manufacture in the United States, Food and Agriculture Organization of the United Nations, Rome, Italy, 1980.

[11] N. Huige, "Brewery by-products and effluents," in Handbook of Brewing, Second Edition, Food Science and Technology, pp. 655–713, CRC Press, 2006.

[12] S. Burrows, Processes of drying yeast, Google Patents, 1976.

[13] H. Tanguler and H. Erten, "Utilisation of spent brewer’s yeast for yeast extract production by autolysis: the effect of temperature," Food and Bioprocess Technology, vol. 86, no. 4, pp. 317–321, 2008.

[14] S. G. Solomon, G. A. Ataguba, and A. Abeje, "Water stability and flotation test of fish pellets using local starch sources and yeast (Saccharomyces cerevisiae)," International Journal of Latest Trends in Agriculture and Food Sciences, vol. 1, no. 1, pp. 1–5, 2011.

[15] A. A. Onifade and G. M. Babatunde, "Supplemental value of dried yeast in a high-fibre diet for broiler chicks," Animal Feed Science and Technology, vol. 62, no. 2-4, pp. 91–96, 1996.

[16] D. O. Adejumo, A. A. Onifade, T. O. Olatunde, and G. M. Babatunde, "The effects of concentration, age and duration of feeding supplemental yeast (Levucell® sb) in a high fibre diet on the performance of broiler chickens," Journal of Sustainable Tropical Agricultural Research, vol. 13, pp. 58–65, 2005.

[17] M. V. L. N. Raju, V. R. Reddy, S. V. Rama Rao, and A. K. Panda, "Yeast: a multifunctional feed supplement for poultry. A review of the benefits of yeast in poultry diets," Poultry International, vol. 45, pp. 16–21, 2006.

[18] A. A. Onifade, R. I. Obiyan, E. Onipede, D. O. Adejumo, O. A. Abu, and G. M. Babatunde, "Assessment of the effects of supplementing rabbit diets with a culture of Saccharomyces cerevisiae using growth performance, blood composition and clinical enzyme activities," Animal Feed Science and Technology, vol. 77, no. 1-2, pp. 25–32, 1999.

[19] G. B. Patel and W. M. Ingledew, "A foaming problem in brewer's yeast slurry destined for drying for animal feed," Journal of the Institute of Brewing, vol. 80, no. 4, pp. 383–386, 1974.

[20] I. Russell, "Yeast," in Handbook of Brewing, F. G. Priest and G. Stewart, Eds., pp. 281–332, Taylor and Francis, Boca Raton, FL, USA, 2006.

[21] A. S. Korkmaz and G. C. Cakiroglu, "Effects of partial replacement of fish meal by dried baker's yeast (Saccharomyces cerevisiae) on growth performance, feed utilization and digestibility in koi carp (Cyprinus carpio L., 1758) fingerlings," Journal of Animal and Veterinary Advances, vol. 10, no. 3, pp. 346–351, 2011.

[22] G. L. Rumsey, J. E. Kinsella, K. J. Shetty, and S. G. Hughes, "Effect of high dietary concentrations of brewer's dried yeast on growth performance and liver uricase in rainbow trout (Oncorhynchus mykiss)," Animal Feed Science and Technology, vol. 33, no. 3-4, pp. 177–183, 1991.

[23] A. N. Lunger, S. R. Craig, and E. McLean, "Replacement of fish meal in cobia (Rachycentron canadum) diets using an organically certified protein," Aquaculture, vol. 257, no. 1–4, pp. 393–399, 2006.

[24] S. Salmur, N. Gulepe, and B. Hossu, "Replacement of fish meal by yeast (Saccharomyces cerevisiae): effects on digestibility and blood parameters forgilthead seabream (Sparus aurata)," Journal of Animal and Veterinary Advances, vol. 8, no. 12, pp. 2557–2561, 2009.

[25] R. O. A. Ozório, L. Portz, R. Borghesi, and J. E. P. Cyrino, "Effects of dietary yeast (Saccharomyces cerevisiae) supplementation in practical diets of tilapia (Oreochromis niloticus)," Animals, vol. 2, no. 1, pp. 16–24, 2012.

[26] L. J. Mun, Evaluation of Spent Brewer's Yeast as an Alternative Fish Feed, Universiti Tunku Abdul Rahman, Petaling Jaya, Malaysia, 2013.

[27] A. Z. Aderolu, M. O. Lawal, T. O. Ali, and O. O. Aarode, "Utilization of Baker's Yeast (Saccharomyces cerevisiae) in the diet of juvenile African Catfish (Clarias gariepinus)," Journal of Scientific Research and Development, vol. 13, no. 1, pp. 19–27, 2011.

[28] M. A. Essa, H. A. Mabrouk, R. A. Mohamed, and F. R. Michael, "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, vol. 320, no. 1-2, pp. 137–141, 2011.

[29] N. E. Ezenwaji, A. Iluno, C. Atama, C. O. Nwaigwe, and C. U. Nwaigwe, "Substitution of soyabean meal with bioactive yeast in the diet of Clarias gariepinus: effect on growth rate, haematological and biochemical profile," African Journal of Biotechnology, vol. 11, no. 91, pp. 15802–15810, 2012.
References:

[30] A. G. J. Tacon, M. Metian, and M. R. Hasan, *Feed Ingredients and Fertilizers for Farmed Aquatic Animals: Sources and Composition*, Food and Agriculture Organization of the United Nations, Rome, Italy, 2009.

[31] J. D. Steckley, G. D. Grieve, G. K. Macleod, and E. T. Moran, "Brewer’s yeast slurry. I. Composition as affected by length of storage, temperature, and chemical treatment," *Journal of Dairy Science*, vol. 62, no. 6, pp. 941–946, 1979.

[32] T. Lovell, *Nutrition and Feeding of Fish*, Kluwer Academic Publishers, Boston, Mass, USA, 1998.

[33] FAO, North African catfish—nutritional requirements, http://www.fao.org/fishery/affris/species-profiles/north-african-catfish/nutritional-requirements/en/.

[34] J. D. Steckley, G. D. Grieve, G. K. Macleod, and E. T. Moran, "Brewer’s yeast slurry. I. Composition as affected by length of storage, temperature, and chemical treatment," *Journal of Dairy Science*, vol. 62, no. 6, pp. 941–946, 1979.

[35] T. Lovell, *Nutrition and Feeding of Fish*, Kluwer Academic Publishers, Boston, Mass, USA, 1998.

[36] S. H. Hoseinifar, A. Mirvaghefi, and D. L. Merrifield, "The effects of dietary inactive brewer’s yeast *Saccharomyces cerevisiae* var. *ellipsoideus* on the growth, physiological responses and gut microbiota of juvenile beluga (*Huso huso*)," *Aquaculture*, vol. 318, no. 1-2, pp. 90–94, 2011.

[37] M. Abdel-Tawwab, "Interactive effects of dietary protein and live bakery yeast, *Saccharomyces cerevisiae* on growth performance of Nile tilapia, *Oreochromis niloticus* (L.) fry and their challenge against *Aeromonas hydrophila* infection," *Aquaculture International*, vol. 20, no. 2, pp. 317–331, 2012.

[38] C. Ran, L. Huang, Z. Liu et al., "A comparison of the beneficial effects of live and heat-inactivated baker’s yeast on Nile tilapia: suggestions on the role and function of the secretory metabolites released from the yeast," *PLOS ONE*, vol. 10, no. 12, Article ID e0145448, 2015.

[39] C. Ran, L. Huang, J. Hu et al., "Effects of dietary live and heat-inactive baker’s yeast on growth, gut health, and disease resistance of Nile tilapia under high rearing density," *Fish & Shellfish Immunology*, vol. 56, pp. 263–271, 2016.

[40] J. Liepins, E. Kovačová, K. Shvirkst, M. Grube, A. Rapoport, and G. Kogan, "Drying enhances immunoactivity of spent brewer’s yeast cell wall *β*-d-glucans," *Journal of Biotechnology*, vol. 206, pp. 12–16, 2015.

[41] G. Reed and T. W. Nagodawithana, *Yeast Technology*, AVI-Van Nostrand Reinhold, New York, NY, USA, 1991.

[42] M. T. Murray and J. Pizzorno, "Kidney stones," in *The Encyclopedia of Natural Medicine*, Atria Paperback, New York, NY, USA, 2012.

[43] C. Burrells, P. D. Williams, P. J. Southgate, and S. L. Wadsworth, "Dietary nucleotides: a novel supplement in fish feeds: 2. Effects on vaccination, salt water transfer, growth rates and physiology of Atlantic salmon (*Salmo salar* L.)," *Aquaculture*, vol. 199, no. 1-2, pp. 171–184, 2001.

[44] P. Li and D. M. Gatlin III, "Nucleotide nutrition in fish: current knowledge and future applications," *Aquaculture*, vol. 251, no. 2–4, pp. 141–152, 2006.

[45] H. S. Murthy and D. M. Gatlin, "Sulfur amino acid utilization: important element of fish nutrition varies by species," *Global Aquaculture Advocate*, vol. 9, pp. 68–69, 2006.

[46] S. Zehra and M. A. Khan, "Total sulphur amino acid requirement and maximum cysteine replacement value for methionine for fingerling *Catla catla* (Hamilton)," *Aquaculture Research*, vol. 47, no. 1, pp. 304–317, 2016.

[47] R. P. Wilson, "Protein and amino acids," in *Fish Nutrition*, J. E. Halver and R. W. Hardy, Eds., pp. 144–179, Elsevier Science, San Diego, Calif, USA, 3rd edition, 2002.