Int.J.Curr.Res.Aca.Rev.2024; 12(5): 84-90

EXCELLENT PUBLISHERS

International Journal of Current Research and Academic Review

ISSN: 2347-3215 (Online) Volume 12 Number 5 (May-2024)

Journal homepage: http://www.ijcrar.com

doi: https://doi.org/10.20546/ijcrar.2024.1205.009

Single Cell Protein as an Alternative Protein Source in Broiler Diet - A Review

Chala Edea*

Ethiopian Institute of Agricultural Research, Debre Zeit Agricultural Research Center, P.O. Box 32, Bishoftu

**Corresponding author*

Abstract

The constant expansion in the world's population leads to an increase in food demand. At the moment, animal protein production is insufficient to supply the world's needs due to challenges in feed quality and quantity. This situation gives place the need for urgent development of alternative and sustainable resources to satisfy this nutritional requirement. In the face of such worldwide issues, single cell proteins derived from the waste organic products is a very useful technology. The objectives of this review were to assess the feed value of single cell protein in broiler diet. Single cell protein microorganisms encompass a wide range of bacteria, marine microalgae, yeasts, and molds has numerous applications in the feed industry. To reduce the cost of protein feedstock for broiler feed, the use of single cell protein (SCP) produced from waste of animal agriculture is an interesting choice. Recent evidence suggests that addition of SCP to the diets of broiler chickens improved body weight and feed conversion efficiency. Many authors observed that higher carcass yield and dressing percentage in birds fed single cell protein containing diet as compared to control diet. Most of the publication reported there were no significant differences in most of gastrointestinal tract. Past research findings have shown that abdominal fat deposition tend to decrease in broiler with increasing level of SCP. According to some author reports the SCP decreases mortality rate. Many research reports found lower the population of salmonella and *E. coli* bacteria in broilers fed diet contained SCP compared with the control. Most scientific publications indicate that higher levels of SCP inclusion (10 % and higher) may be harmful to the broilers in terms of productive performance. Moreover, reviewed research works have shown that SCP attractive features as a nutrient supplement for broiler.

Article Info

Received: 18 March 2024
Accepted: 28 April 2024
Available Online: 20 May 2024

Keywords

Single cell protein, broiler diet, food insecure, protein deficit.

Introduction

The growing global population and the negative consequences of climate change, particularly draught, necessitate the development of new and novel methods for producing sufficient food in a sustainable manner. Global demand for high-quality, protein-rich foods will continue to rise as the world's population and income levels rise. Many developing countries are food insecure, with the majority not only lacking adequate food, but also unable to afford a balanced diet, and protein deficit is becoming a big issue for humanity. The effect of low chicken production and productivity, along with issues in feed quality and quantity, resulted in unaffordable poultry products for the majority of society.

Feed is the major limitation in the poultry industry, accounting for 60-70% of total broiler chicken production costs. Modern fast-growing broiler chickens require a high protein content with a balanced amino acid

content. Soybean meal is the most desired vegetable protein due to its high protein and balanced amino acid content (Hombegowda *et al.,* 2021). Recent price and availability fluctuations, as well as the inclusion of hulls and antinutritional factors (Erdaw *et al.,* 2018), have reduced its use in broiler production. Fish meal, meat meal, bone meal, blood meal, and hydrolyzed feather meal are examples of animal protein sources. However, their use is restricted due to quality variations and the existence of harmful microorganisms.

In view of the above facts, there is continuous search for alternative high quality protein feedstuff that can improve broiler production performance. Single cell protein (SCP) is one of the possible alternative protein sources. SCP products, which are protein meals based on microbial or algal biomass, have the ability to meet this need. It is a very fast way of producing protein compared to the production of protein through cultivation of agricultural crops or animal farming (Pourelmi *et al.,* 2018). The SCP can be manufactured from residual streams from many sectors, allowing for low-cost production (Nasseri *et al.,* 2011). Furthermore, SCP manufacturing can be done in bioreactors, freeing up agricultural area. SCP can be included up to 5% or 30-40% of total CP in broiler diets with enhanced weight gain, feed conversion ratio (FCR), and economic efficiency, according to many research (Zhang *et al.,* 2013). Therefore, the objectives of this paper are to review the use of single cell protein in broiler diets.

Over view of SCP

Single cell protein is a broad term for crude or refined protein derived from bacteria, yeasts, molds, or algae, microorganisms that typically contain more than 40% crude protein on a dry-weight basis. It is protein generated from microorganism cells that have been cultured on various carbon sources for synthesis. SCP contains nutrients other than proteins, including as fats and vitamins. Single cell protein (SCP) is one of the materials for appropriate protein source and feed formulation since it can be used as a protein supplement to replace expensive protein materials and large amounts of SCP can be produced in a short period of time (Chee *et al.,* 2019; Ritala *et al.,* 2017). It is seen as a promising product for addressing the issue of high protein feed prices (Golaghaiee *et al.,* 2017; Reihani & Khosravi Darani, 2018). According to Alloul *et al.,* (2018), SCP can be grown on industrial wastewater to produce protein feed while also treating wastewater in environmental management.

On a dry matter basis, SCPs contain roughly 60 to 80% protein. SPCs are high in important amino acids including methionine and lysine. Single cell protein has been produced using conventional substrates such as starch, fruit, molasses, and fruit waste, as well as unusual substrates such as petroleum byproducts, ethanol, natural gas, lignocellulosic biomass, and methanol.

Microbial protein uses waste or raw materials and microorganisms on a large scale to convert substrate, enhancing microbial growth and production. Furthermore, seasonal variations have little effect on the process's performance. SCP products include a high concentration of nucleic acid (6-10%), which raises serum uric acid levels. This level of access causes uric acid precipitation, which can lead to health concerns such as the production of gout and kidney stones.

Effect on performance and feed utilization

Various studies have found that a single cell has varying effects on broiler body weight, feed intake, and feed conversion ratio. With an increase in the dietary content of Single Cell Protein, there was a decrease in broiler chicken weight gain, feed conversion, and feed intake (Pirmohammadi *et al.,* 1999; Jassim *et al*., 1986). Similar depression was observed on the growth of broiler chickens fed methanol-utilizing bacteria (Plavnik, 1981).

Schoyen *et al.,* (2007) found that replacing SBM or fishmeal with 6% bacterial protein meal reduced feed intake. Waldroup and Payne (1974) also showed that the powdered texture of the bacterial protein contributes to the reduction in feed intake. White and Balloun (1977) showed similar alterations in feeding behavior at 9% and 12% SCP addition in meals. According to (An et *et al.,* 2018), replacing SBM with Corynebacterium ammoniagenes-derived SCP at 5% in broiler diet resulted in decreased feed consumption, which was connected with free adenine or unknown components contained in bacteria-derived SCP. Overland *et al.,* (2010) indicated that reduced feed intake was due the decreased palatability with increasing bacterial protein autolysate associated with the greater proportions of free amino acids and resulted in decreased performance of birds.

White and Balloun (1977) investigated the SCP replacing up to 15% of the soybean meal in the feed of broilers. The powdery consistency of SCP tended to reduce BWG and feed conversion efficiency when fed at 9% or more of the mash form diet. Interestingly, pelleting diets containing SCP eliminated these adverse effects. When

diets were pelleted, substitution of SCP for soybean meal, on a weight-for weight basis at levels up to 15% of the diet produced greater and more efficient gains. Anonymous (1989) mentioned that free lysinoalanine is more toxic than covalently lysinoalanine in food proteins. This effect may be due to differences in absorption and copper-binding affinity between dietary LL and DL isomers of lysinoalanine. Primo hammadi *et al.,* (1999) mentioned three types of SCP up to 6% of broilers diet had no adverse impacts on performance. Manal and Abou El Nagha (2012) reported higher body weight gain in broilers fed SCP at the level of 0.3, 0.5 and 0.7%. Shareef and Al-Dabbagh (2009) also reported improved body weight gain using yeast as SCP at the level of 2% in broiler diet. Pourelmi *et al.,* (2018) reported that inclusion of 10% and 15% bacterial cell protein (replacing soybean meal) in broiler diets resulted in significantly decreased body weight gain compared to control and 5% bacterial cell protein diet groups.

According to Waldroup and Payne (1974) and Pourelmi *et al.,* (2018), incorporating SCP at 10% and 15% in broiler diets in place of SBM resulted in decreased FCR when compared to control. Overland *et al.,* (2010), on the other hand, found improved FCR as a result of 12% bacterial protein autolysate substituting SBM in broiler diet. The use different levels of single cell protein improved feed intake and weight gain in broilers, resulting in a reduction in feed conversion factor (Nazarizadeha *et al.,* 2020). Several factors influence the beneficial effects of yeasts in broiler diets. Initially, the yeast single-cell protein can operate as a growth stimulator due to the presence of protein and balanced amino acids, vitamins, and minerals (Amata, 2013), as can the yeast cell wall due to the presence of Glucans and mannan oligosaccharides. To the positive effects of yeasts on mucus and intestinal wall, it improves weight gain in poultry, which increases Willy's height, provides intestine conditions for the growth and activity of beneficial bacteria in the intestine, and improves intestine pH to increase digestion and absorption of nutrients, resulting in weight gain and a decrease in feed conversion factor (Abdel-azeem, 2002).

Waldroup and Payne (1973) evaluated a single-cell bacterial protein in broiler diets and reported that using this single-cell bacterial protein enhanced weight gain, feed intake, and feed conversion factor compared to the control group. According to the findings of Manal and Abou (2012), adding yeast to broiler diets increases weight gain and feed intake which is similar with the findings of Nazarizadeha *et al.,* (2020).

Effect of Single cell protein Carcass Performance

Najib (2014) observed that replacing SBM in the broiler ration with SCP at 5%, 10%, and 15% had no influence on dressing percentage. Whereas, Overland *et al.,* (2010) observed that inclusion of bacterial protein autolysate at 8% and 12% of the diet replacing SBM in the broiler diet showed significantly lower carcass weight and dressing percentage compared to the control diet group. Yadav *et al.,* (2018) also observed that supplementation of probiotic (*Bacillus subtilis*) at the level of 1 mg/g of diet has significant effect on weight of the breast muscle.

According to Nahanshon *et al.,* (1994), introducing bacterial probiotics to the die improves protein availability and increases carcass weight as the protein content of the diet increases. An *et al* (2018), on the other hand, observed, that incorporating graded levels of Corynebacterium ammoniagenes derived SCP up to 5% (50 g/kg) of ration by replacing SBM in the broiler diet had no significant effect on the relative weight of breast muscle. It was suggested that the difference in dressing % could be related to the use of a different strain of yeast or SCP or manipulation of other components in the diet.

Schoyen *et al.,* (2007) observed replacing SBM and fish meal with graded level of bacterial protein meal (2%, 4%, and 6%) has no significant on weight of thigh. The drumsticks percentage of live weight among various treatments and main components (SCP level and protein source) were non-significant across all diets. The abdominal fat percentage of live weight were found comparable among various treatments and main components (SCP level and protein source) Overland *et al.,* (2010).

Impact on intestinal morphology

According to Inam *et al.,* (2017), including *Saccharomyces cerevisiae* in the broiler starting ration at rates of 5%, 10%, and 15% had no influence on intestinal morphology such as villus height and crypt depth.

In contrast, Samanya and Yamauchi (2002) found that adding *Bacillus subtilis* at 0%, 0.2%, 0.5%, and 1% levels to a basal mash diet for 28 days resulted in considerably longer villus length in the 0.2% group compared to the control group. Latorre *et al.,* (2017) reported a significant decrease in the villi length: crypt depth ratio, which he attributed to a larger presence of insoluble fiber in the intestinal digesta, which increased cellular turnover.

According to Nazarizadeha *et al.,* (2020), the usage of yeast single-cell protein raised Willy height and decreased crypt depth in recipient broilers. Increasing the Willy height and decreasing the crypt depth enhances nutritional absorption and gastrointestinal tract function, resulting in increased weight gain and a lower feed conversion factor (Pirgozliev *et al.,* 2008).

Abdominal fat and GIT

Schoyen *et al.,* (2007) suggested that abdominal fat deposition tend to decrease in broiler with increasing level of SCP. These findings are in contrast with Overland *et al.,* (2010); Najib (2014) and Hombegowda *et al.,* (2021) who reported that abdominal fat deposition incline to increase in broiler with increasing level of SCP.

Najib (2014) observed significantly different liver weight in broiler birds fed 5%, 10%, and 15% SCP based diets. Inam *et al.,* (2010), on the other hand, found no significant difference in gizzard, heart, or liver weight in broiler chickens fed diets containing 5%, 10%, or 15% *Saccharomyces cerevisiae* instead of SBM. An *et al.,* (2018) showed that including graded levels of Corynebacterium ammoniagenes derived SCP up to 5% of broiler feed had no effect on the relative weights of Fabricious' spleen and bursa. Pourelmi *et al.,* (2018) found no influence on the absolute weights of Fabricious' liver, gizzard, spleen, and bursa owing to SCP inclusion at 5%, 10%, and 15% in broiler diets replacing SBM. Further, non-significant difference in giblet and lymphoid organs weight was noticed for main component protein source. Ozsoy and Yalcin (2011) also reported no effect of yeast-based SCP on weight of gizzard, liver and heart in broiler chicks fed diet having 1 to 3% yeast.

Immune response and survivability

According to Pourelmi *et al.,* (2018), there is a positive association between dietary SCP levels and mortality rate. Birds fed diets containing no SCP and 5% SCP showed 1.19% mortality, but birds fed diets containing 10% and 15% SCP showed 40% and 100% mortality, respectively (Pourelmi *et al.,* 2018). Ashraf (1981) also observed that increasing dietary SCP enhanced chicken mortality. He speculated that it was due to a lack of selenium. In contrast, other researchers found that increasing the proportion of yeast single cell protein in broiler diets reduced mortality (Gao *et al.,* 2008; Yalcin *et al.,* 2008). The difference in response may be due to SCP product formulation and SCP origins. The black box of the SCP might be related to lysinoalanine, N6-(DL-2-amino-2- carboxyethyl)-L-lysine which is an unusual amino acid.

Effect of feeding of SCP on blood biochemical characteristics of broiler chicken

The effect of cultured yeast on poultry performance was investigated in a study by Panda *et al.,* (2005), and it was reported that the use of cultured yeast had no significant effect on the blood biochemical parameters of broilers, which contrasts with the report of (Nazarizadeha *et al.,* (2020) who reported that the use of single cell yeast protein has a significant effect on blood biochemical parameters. Yalcin and Ozsoy (2011) investigated the effect of yeast use on the performance and biochemical parameters of broiler serum and immune System, and reported that the use of cultured yeast in broiler diets had no significant effect on blood biochemical parameters such as total protein, cholesterol, triglyceride, and alanine, which contrasted with the results of (Nazarizadeha *et al.,* 2020).

Blood hemoglobin, glucose, total protein, albumin, globulin, AST, and ALT levels all decreased significantly, but uric acid increased. There was no effect on serum triglyceride or cholesterol levels, however. Reduced hemoglobin, total protein, albumin, globulin, and glucose levels indicate malnutrition, which is reflected in significant difference in feed intake of experimental birds with increased level of SCP (Taraknath *et al.,* 2023) which agrees with the findings of Aderolu *et al.,* (2007) and Rameshwari *et al.,* (2005). Hyperuricemia developed, possibly due to starvation, and was followed by significant tissue deterioration and renal disease (Chandra *et al.,* 1983).

Effect of single cell protein on growth of caecum bacteria

Nazarizadeha *et al.,* (2020) showed that the use of yeast single-cell protein in broiler diets reduced the population of Salmonella and *E. coli* bacteria and provided conditions for the growth of beneficial bacteria such as Lactobacillus, which, according to the obtained results, increasing the population of Lactobacillus bacteria was observed in broilers receiving yeast single-cell protein. Improving broilers feed intake and weight gain in yeast single-cell protein receiving treatments can be due to a reduction in the number of harmful bacteria and an increase in the number of beneficial bacteria due to the

use of yeast single cell protein. Researchers believe that the use of yeast in broilers diet can develop the digestive tract of broilers and maintain the integrity of the mucous membrane of the intestine (Iji *et al.,* 2001).

Conclusion and Recommendation

Single cell protein is a more sustainable, high-quality, safe and traceable alternative to conventional protein sources used in broiler diet. Reviewed research works have shown that SCP attractive features as a nutrient supplement for broiler. It basically comprises of protein, carbohydrate, fats, water and elements like phosphorous and potassium and essential amino acids. Thus, the use of SCP as an alternative nutrient supplement can solve the problem of feed scarcity of rapidly growing population especially in a developing country like Ethiopia. Many research works concluded that higher levels of SCP inclusion (10 % and higher) may be harmful to the broilers in terms of productive performance. In future, research on the single cell protein in broiler diets should continue in order to establish the most appropriate conditions at which the single cell protein would exert their positive effect at the greatest extent in order to produce high quality and healthy meat.

References

Abdel-Azeem, F., 2002. Digest on, neomycin and yeast supplementation in broiler diets under Egyptian summer conditions. J. Egypt Poult. Sci., 22: 235-257.

Aderolu A Z, Iyayi E Z and Onilude A A. 2007. Performance, organ relative weight, serum and haematology parameters in broiler finisher fed biodegraded brewers dried grain. Pakistan Journal of Nutrition 6: 204–08.

Amata, I. A., 2013. Yeast single cell protein: Characteristics and metabolism. Int. J. appl. Biol. Pharma. Tech., 4:158-170.

An B K, Choi Y I, Kang C W, Lee K W. Effects of dietary Corynebacterium ammoniagenes-derived single cell protein on growth performance, blood and tibia bone characteristics, and meat quality of broiler chickens. J Anim Feed Sci 2018; 27:140-7. https://doi.org/10.22358/jafs/91966/2018

Anonymous. (1989). Mechanism of toxicity of lysinoalanine. Nutr. Rev. 47, 362-364.

Ashraf M. (1981). Nutritional evaluation of methanol-based yeast single-cell protein for growing pullets, laying hens and reproducing chickens, Ph D. Thesis. Iowa State Univ., Ames, Iowa.

Chandra M, Singh B, Soni G L and Ahuja S P. 1983. Real and biochemical changes produced in broilers fed high protein, high calcium, urea-containing and vitamin A deficient diets. Avian Diseases 28: 1–6.

Chee, J. Y., Lakshmanan, M., Jeepery, I. F., Hairudin, N. H. M., & Sudesh, K. (2019). The potential application of Cupriavidusnecator as polyhy-droxyalkanoates producer and single cell protein: A review on scien- tific, cultural and religious perspectives. Applied Food Biotechnology, 6, 19–34.

El-Naga M K A. Effect of dietary yeast supplementation on broiler performance. Egyptian Poult Sci J 2012; 32:95-106.

Erdaw M M, Perez-Maldonado R A and Iji P A. 2018. Physiological and health-related response of broiler chickens fed diets containing raw, full-fat soya bean meal supplemented with microbial protease. Journal of Animal Physiology and Animal Nutrition 102: 533–44

Gao J., Zhang H. J., YU S. H., WU S. G., Yoon I., Quigley J., Gao Y. P. and QI G. H. (2008). Effects of yeast culture in broiler diets on performance and immunomodulatory functions. J. Poult. Sci. 87, 1377-1384

Hassanein S M, Soliman N K. Effect of probiotic (*Saccharomyces cerevisiae*) adding to diets on intestinal microflora and performance of Hy-line layers hens. J Am Sci 2010; 6:159-69.

Hombegowda G P, Suresh B N, Shivakumar M C, Ravikumar P, Girish B C, Rudrappa S M and Indresh H C. 2021. Growth performance, carcass traits and gut health of broiler chickens fed diets incorporated with single cell protein. Animal Bioscience 34: 1951–62

Iji P A, Sak A A and Tivey D R (2001) Intestinal structure and function of broiler chickens on diets supplemented with a mannan oligosaccharide. The Science of Food and Agriculture. 81: 1186-1192.

Inam M, Khan S, Sultan A, Khan N A. Effect of *Saccharomyces cerevisiae* on overall performance of broilers at starter phase. Int J Biosci 2017; 11:42-53.

Jassim A H, Hussain N A, Muhssin A A, Alak B M, Al-Haidary S Y. The effect of using single cell protein in productive performance, level of nucleic acids and histopathological changes broilers. Journal of Agriculture and Water

Resources Research, Animal Production. 1986; 5:275-283.

Latorre J D, Hernandez-Velasco X, Vicente J L, Wolfenden R, Hargis B M, Tellez G. Effects of the inclusion of a Bacillus direct-fed microbial on performance parameters, bone quality, recovered gut microflora, and intestinal morphology in broilers consuming a grower diet containing corn distillers dried grains with solubles. Poult Sci 2017; 96:2728-35. https://doi.org/10.3382/ps/pex082

Leeson S. and Summers J. D. (2001). Scott's Nutrition of the Chicken. University Books, Guelph, Ontario, Canada

Leeson S. and Summers J. D. (2005). Commercial Poultry Nutrition, Nottingham University Press, Nottingham, United Kingdom.

Loddi M M, Nakaghi L S O, Tucci F M, Hannas M I, Moraes V M B and Ariki J (2002). Mannan oligosaccharide and organic acids on intestinal morphology integrity of broilers evaluated by scanning electron microscopy. Proceeding of 11thEuropean Poultry Sciences Conference, Bremen, Germany. Pp. 121-126.

Manal K. and El-nagha A. (2012). Effect of dietary yeast supplementation on broiler performance. Egypt Poult. Sci. 32, 95- 106

Nahanshon S N, Nakaue H S, Mirosh L W. Production variables and nutrient retention in single comb white leghorn laying pullets fed diets supplemented with direct-fed microbials. Poult Sci 1994; 73:1699-711. https://doi.org/10.3382/ps.0731 699

Naila Chand, Ihsanuddin and Rifat Ullah Khan. Replacement of Soybean Meal with Yeast Single Cell Protein in Broiler Ration: The Effect on Performance Traits. Pakistan J. Zool., vol. 46(6), pp. 1753-1758, 2014

Najib H. Feeding value of single cell protein produced from date palm (Phoenix dactylifera) fruits for broiler chickens. Ann Res Rev Biol 2014; 4:2406-13. https://doi.org/10.9734/ARRB/2014/9524

Nasseri A. T., Rasoul-Amini S., Morowvat M. H. and Ghasemi Y. (2011). Single cell protein: Production and process. Am. J. Food Technol. 6, 103-116.

Nazarizadeha *et al*., 2020. Evaluation of single cell protein replacement (pl 68) by soybean meal in broiler chickens. Bioscience Research, 2020 volume 17(2): 1315-1322

Overland M, Schoyen H F, Skrede A. Growth performance and carcase quality in broiler chickens fed on bacterial protein grown on natural gas. Br Poult Sci 2010; 51:686-95. https://doi.org/10.1080/00071668.2010.522556

Ozsoy B. and Yalcin S. (2011). The effects of dietary supplementation of yeast culture on performance, blood parameters and immune system in broiler turkeys. Ankara Univ. Vet. Fak. Derg. 58, 117-122.

Panda, N., Rajashekher Reddy, A., Reddy, G. V. N. and Keshav Reddy, A. S. (2005). Effect of feeding yeast culture on the performance of broilers. College of Veterinary Science Acharya N. G Ranga Agricultural University.

Pirgozliev V, Murphy T C, Owens B, George J and McCann M E (2008) Fumaric and Sorbic acid as additives in broiler feed. Research in Veterinary Science. 84(3): 387-394.

Pirmohammadi R., Shivazad M. and Yousof Hakimi A. (1999). Feeding value of Iranian produced single cell protein for broilers. Iranian J. Agric. Sci. 30, 277-286

Plavnik I, Bornstein S, Hurwitz S. Evaluation of Methanol-grown bacteria and hydrocarbon-grown yeast as sources of protein for poultry: Studies with young chicks. British Poultry Science. 1981; 22:123-140.

Pourelmi M R, Seifi S, Abdoullahi K A R and Khoshbakht R. 2018. Evaluation of single cell protein as a non-conventional feedstuff in broilers feeding. Iranian Journal of Applied Animal Science 8: 317–24

Rameshwari K S and Karthikeyan S. 2005. Distillery Yeast Sludge (DYS) as an alternative feed resource in poultry. International Journal of Poultry Science 4: 787–89

Ritala, A., Hakkinen, S. T., Toivari, M., & Wiebe, M. G. (2017). Single cell protein—state-of-the-art, industrial landscape and patents 2001– 2016. Frontiers in Microbiology, 8, 2009. https://doi.org/10.3389/fmicb.2017.02009

Samanya M, Yamauchi K E. Histological alterations of intestinal villi in chickens fed dried *Bacillus subtilis* var. natto. Comp BiochemPhysiol A: Mol IntegrPhysiol 2002; 133:95- 104. https://doi.org/10.1016/S1095-6433(02)00121-6

Schoyen HF, Svihus B, Storebakken T, Skrede A. Bacterial protein meal produced on natural gas replacing soybean meal or fish meal in broiler chicken diets. Arch Anim Nutr 2007; 61:276-91. https://doi.org/10.1080/17450390701431953

Shareef A. M. and Al-dabbagh A. S. A. (2009). Effect of probiotic (*Saccharomyces cerevisiae*) on performance of broiler chicks. Iranian J. Vet. Sci. 23, 23-29

Taraknath Bhunia, Barun Roy and Tapan Kumar Das. 2023. Growth performance of broiler chicken fed diet with single cell protein. Indian Journal of Animal Sciences 93 (5): 501–504, May 2023/Article

Waldroup P. W., Payne J. R., 1974. The feeding value of methanol derived single cell protein for broiler chicks. Poult. Sci. 53, 1039–1042, https://doi.org/10.3382/ps.0531039

White W. B. and Balloun S. L. (1977). The value of methanol derived single-cell protein for broilers. Poult. Sci. 56, 266-273.

Yadav M, Dubey M, Yadav M, Shankar K S. Effect of supplementation of probiotic (*Bacillus subtilis*) on growth performance and carcass traits of broiler chickens. Int J Curr Microbiol Appl Sci 2018; 7:4840-9. https://doi.org/10.20546/ijcmas.2018.708.510

Yalcin S., Ozsoy B. and Erol H. (2008). Yeast culture supplementation to laying hen diets containing soybean meal or sunflower seed meal and its effect on performance. J. Appl. Poult. Res. 17, 229-236

Zhang H Y, Piao X S, Li P, Yi J Q, Zhang Q, Li Q Y, Liu J D and Wang G Q. 2013. Effects of single cell protein replacing fish meal in diet on growth performance, nutrient digestibility and intestinal morphology in weaned pigs. Asian Australasian Journal of Animal Science 26: 1320–28.

How to cite this article:

Chala Edea. 2024. Single Cell Protein As An Alternative Protein Source In Broiler Diet - A Review. *Int.J.Curr.Res.Aca.Rev.* 12(5), 84-90. doi: https://doi.org/10.20546/ijcrar.2024.1205.009