Pigeon Pea (*Cajanus Cajan*) Seed Meal as a Dietary Protein Source for Tank Reared Nile Tilapia (*Oreochromis Niloticus*) Fish: A Mini-Review

Millicent Khakhathi Ralinala, Felix Fushai, Joseph Jimu Baloyi and Jabulani Ray Gumbo

***Abstract*—** The review explores the potential of tank rearing of Nile Tilapia (*Oreochromis niloticus*) fish on pigeon pea (*Cajanus cajan (L)*) seed meal as a dietary protein source. Aquaculture is the fastest growing food production sector in the world. Global consumption of fish has doubled over the past years with the developing world responsible for over 90% of this growth. Therefore, aquaculture has the potential to dramatically improve rural living standards, food security and can combat poverty through income generation, employment creation and the efficient use of local resources. For commercial production, high quality diets are required to achieve optimal growth. Fish feed accounts for at least 60 % of the total cost of commercial fish production with protein and energy the most critical nutrient supplements to support fish growth. Despite the high crude protein and energy values, tropical legume seeds such as the Pigeon pea (*Cajanus Cajan L.*) have not been used widely in fish feeds.

***Keywords*—** local fish feed, aquaculture, rural livelihoods, pigeon pea

I. Introduction

Aquaculture is the “farming” of aquatic organisms including fish, molluscs, crustaceans and aquatic plants, which involves controlled interventions during the rearing process, to enhance production, such as regular and optimal stocking, feeding, protection from predators and many other necessary management (United Nations Food and Agriculture Organization [1]. Aquaculture has the potential to sustainably supplement capture fisheries and significantly contribute to feeding the world’s growing population [2]. It accounts for approximately half of the world’s total supply of food fish and is the fastest growing sector of the world food economy [1], currently accounts for more than 30% of all fish consumed and increasing by more than 10% per year[3]. Utilization of simple culture technologies and minimal inputs from within traditional small-scale systems have been used for centuries. Most fish farmed in these systems benefit local communities and minimize deleterious environmental impacts. In developing countries, these traditional aquaculture systems are offer many benefits which include food security [2].

Worldwide, fish consumption per capita has increased at an average of 9.9 kg in 1960; to 19.2 kg in 2012 and 20.5 kg in 2018 [1]. In developing countries, fish is considered among key sources of food and income for many communities [4]. A fish portion of 150 g provide 50 – 60 % daily required protein of an adult [1], However, consumption is subject to local and seasonal production. Over the previous 30 years, aquaculture has been rising at an annual rate of 8.8 % [5]. The global aquaculture production has increased from 13 % to 42 %, with the global wild capture production under threat of overexploitation in certain regions [1]. Increased global aquaculture will likely therefore increasingly significantly complement the global wild capture production [1].

About 89% of the population of Limpopo Province of South Africa is classified as rural [6]. Agriculture plays a major role in the economic growth and development of the Limpopo Province [7]. The province is one of the richest agricultural regions suited for production of cereals and legumes like pigeon pea, which are main ingredients in livestock, including fish like tilapia (*Oreochromis mozambicus*).

II. Biology of Tilapia Fish

Tilapia belongs to the family Cichlidae, in the order Perciformes. Tilapia originated from Africa and the Middle East, where it has been cultured for years. The first tilapia was farmed in the ancient Egypt over 4000 years ago [8]. Tilapia covers the three main genera: *Oreochromis*, *Sarotherodon*, and *Tilapia* species. However, these genera cover over 70 known species in total [8]. The most farmed fish species in the world is Nile tilapia (*Oreochromis niloticus*) [9]. Apart from Antarctica, Nile tilapia culture has been practiced throughout the tropical, subtropical and temperate regions [10]. Other commonly farmed species that similarly grow fast are the Israeli tilapia (*Oreochromis aureus*) and the Mozambique tilapia (*Oreochromis mossambicus*) [8].

Tilapia can be easily cultured in rural conditions because they are low on the aquatic food chain, feeding on algae and

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Ms Millicent Khakhathi Ralinala is with Jilin University, China

Dr Felix Fushai is with the Department of Animal Science, University of Venda

Prof Joseph Jimu Baloyi is with the Department of Animal Science, University of Venda

Prof Jabulani Ray Gumbo is with the Department of Hydrology & Water Resources, University of Venda

plant materials [11]. Among the cultured species, tilapia is in third place in terms of production, after carps and salmon, respectively [11]. In terms of temperature and salinity, tilapia species adapt very well and reproduce very fast in favourable conditions. However, tilapia is naturally mostly found in streams, big lakes, and oceans [12]. The survival of fish in extreme temperatures affects the size and health [11]. Optimal temperature is therefore important to achieve the potential growth of tilapia.

Oreochromis mossambicus has many features that make it a good candidate for aquaculture, which explains its status as the most farmed fish [13]. Relative other species, advantages include wide environmental tolerance, which gives it ability to survive in poor water conditions, grow fast, breed easily with no need for artificial interventions, and feeding on a wide range of feeds such as insect larvae, algae, fish finger lings, worms, plants, and detritus [14]. They are resistant to both environmental and management related stress and to diseases, can withstand high ammonia levels, salinity and extreme temperatures [11].

III. Tilapia tank culture

When there is insufficient water and land, tank culture is the best alternative to pond and cage culture. Tilapia grow well in tanks at high density subject to maintenance of good water quality through aeration and continuous water exchange, renewing dissolved oxygen and removing wastes [9]. Tank culture advantages include higher stocking density, easy management and effective control of environmental parameters. Feeding and harvesting require minimal time and labour, with easy disease control and more yield per unit of land [15]. Disadvantages are that fish must be fed with a complete diet including supplementary vitamins and minerals given limited access to natural foods. The production cost is significantly increased by the need for artificial aeration and water pumping. Recirculation systems require substantially more attention and are expensive, while high fish density can cause stress and disease breakout [15].

In tank culture, water quality is important. Exchanging water continuously is necessary to maintain optimum water quality. Balanced water exchange is critical to avoid the accumulation of toxic substances from unutilised feed and excretory metabolites [11]. About 20 % of water exchange is required per day and if exceeded this may stress the fish and lead mortality and poor growth [16].

IV. NUTRITIVE VALUE OF SELECTED LOCALLY AVAILABLE FISH FEED

Previous studies have evaluated the nutritive value of different locally available feeds for tilapia fish [15-18]. Adewulo [17] evaluated sweet potato (*Ipomoea batatas*) leaf meal as dietary ingredient for *Tilapia zilli* fingerlings. This study agrees favourably with Soko and Kang˒ombe [18] on the development of least cost formulated feed for *Tilapia rendalli* in tank based grown-out culture system. The plant protein was locally available and low-cost ingredients were used in formulating the fish feed. The local fish feed was fed to *Tilapia rendalli* in tank based on grow-out culture system and improved their growth which was evident by the good percentage increase in weight and acceptable feed utilization indices.

V. Importance of grain legumes in rural farming systems

Legumes are important crops because of the high protein content (Table 1) and fixation of nitrogen into the soil [19]. Legume seeds are highly priced stock feeds due to the high content of protein [20], amino acids, fibre, minerals, and vitamins [21]. A wide range of grain legumes are used as ingredients for animal feed and human consumption [22]. Commercially important legume species include the Common bean *(Phaseseolus vulgaris)*, Chickpea *(Cicer arietinum)*, Mungbean *(Vigna radiata)*, Jack bean *(Canavalia ensiformis)*, Bambara groundnut *(Vigna subterranea)*, Cowpea *(Vigna unguiculata)*, Common pea *(Pisum sativum)*, Faba bean *(Vicia faba)*, Soyabean *(Glycine max)*.

Table I: Crude Protein content (Dry Matter basis) of common grain legumes.

Species	% crude protein	reference
African yam bean	25.2	[23]
Bambara groundnut	19.4	
Jack bean	18.8	
Lablab	22.5	
Lima bean	21.6	
Pigeon pea	21.6	
Soya bean	33.5	
Cowpea	20.9	[24]
Common pea	25.5	
Rice bean	25.0	

VI. Anti-Nutrition Factors In Legume Feeds

The most limiting factor in the use of grain legumes as feed are anti-nutritional factors, which reduce the nutritive value [25]. Anti-nutritional factors affect physiological processes such as digestion, absorption, and respiration [26] sufficiently to affect growth when fed unprocessed and at high dietary levels [27].

Examples of some anti-nutritional factors found in legumes and grains:

- Phytate which reduces the absorption of minerals like iron, zinc, magnesium and calcium, by binding them making them unavailable. In small grains 80 % of phytate is in the aleurone layer [28]. In legume seeds 90 % of phytate is found in protein bodies of the endosperm [29]. It can be reduced through enzyme addition such as phytate [30].
- Protease inhibitor inhibits the digestive enzymes which interfere with protein digestion. They cause pancreatic enlargement and decrease growth [31].
- Tannins are antioxidant polyphenol which impair the digestion of nutrients and reduce the absorption of vitamin B12 and can be eliminated by dehulling, autoclaving or alkali treatment [30]. Tannins reduce feed utilization in animals, reduce palatability and growth rate, bind dietary protein and digestive

enzymes formulating complexes that are not digestible [31].

- Lectins are protein which interfere with the absorption of nutrients in the intestine and they can be removed by heat treatment or autoclaving [30].

VII. Processing Of Legume Grains

Processes such as soaking, boiling, fermentation, sprouting, wet heating and sun-drying of plant ingredients before feed formulating of diets reduce anti-nutritional factors and improve fish growth together and feed intake [32]. The final quality of a plant protein source depends upon the processing method. Soaking pigeon pea for 6-8 hours reduced lectins by 38-50 %, tannins by 13-25 % and protease inhibitors by 28-30 % [32].

VIII. Nutrient Requirements And Diets For Fish

The prepared complete diets supply all the ingredients (protein, carbohydrates, fats, vitamins, and minerals) required for the fish growth performance and health status. Most used complete diets contain protein (18 – 50 %), lipid (10 – 25 %), carbohydrate (15 – 20 %), ash (< 8.5 %), phosphorus (< 1.5 %), water (<10 %), and with certain vitamins and minerals [33]. Complete diet is mainly required for fish reared in high density indoors and in cages because they cannot forage freely on natural feeds [33], because dietary proteins are the most important nutrient component of complete formulated diets [34].

Supplemental diets are prepared to help support the natural feed available in ponds, such as algae, insects and many others. These diets are devoid of vitamins and minerals but contain protein, carbohydrates and lipids and hence there is a need to supplement or fortify [33]. The floating feed is important as this allows the farmer to observe the feeding activity and if possible, increase the fish feed [35]. Another study has focussed on the dietary requirements of tilapia feeds with alternative protein sources. These include fishery and terrestrial animal by-product meals, oilseed meals, aquatic plants, single-cell proteins, legumes and cereal by-products [11].

Generally, protein quality of dietary ingredients is the most important factor affecting fish performance, and protein digestibility is the measure of its availability to fish. Protein quality of dietary protein sources depends on the composition of amino acids and their digestibility. Essential amino acid deficiency leads to poor utilization of the dietary protein and consequently reduces growth and decreases feed efficiency [35]. Dietary ingredients should also supply enough energy to support the fish's vital life processes of nutrient transport, growth and reproduction [32].

Apart from the energy supply, lipids serve to transport fat soluble vitamins. Inclusion in plant-based fish diets is critical to spare dietary protein from metabolism for energy, given twice the energy density of proteins and carbohydrates. Fatty acids of the omega 3 and 6 families are essential for Tilapia [33].

Carbohydrates, including free sugars, starches, and readily fermented fibre [37] are considered energetically efficient and cheapest energy source in fish diets. In addition to conversion to fat, fish transiently store carbohydrate for energy as glycogen, which is mobilized as necessary to satisfy the energy demands [33].

Vitamins are organic compounds that can be classified as water-soluble or fat-soluble. In the fish diet, vitamins are required for growth performance, metabolism, reproduction, good health. Fish cannot synthesize vitamins; they are essential form the diet. Vitamin C (ascorbic acid) is a powerful antioxidant which helps maximize the immune response [37]. Deficiencies result in reduced growth, skeletal deformation, haemorrhages, poor wound healing and many other disorders [37].

Minerals are inorganic elements which consist of macro and micro minerals. The minerals are essential in the diet for the normal functioning of the body. In fish, macro-minerals are required to regulate osmotic balance, cell formation and skeletal formation while micro-minerals are required as components of enzymes and hormone functioning [37]. Fish compensate for dietary mineral's deficiencies by absorption of certain minerals from water through their gills and skin [33].

IX. Productivity And Nutritive Value Of Pigeon Pea

Pigeon pea is an important grain legume crop grown in Eastern and Southern Africa, Asia and Central America [38]. It is in the Kingdom plantae, Order Fabales, Family Fabaceae, Genus Cajanus and Species *C. Cajan* [39]. In Africa, subsistence farmers in the semi-arid areas mainly grow it [40] because It is a nutritious legume; a cheap source of protein for many poor households and it is a nitrogen-fixing legume, which has the potential to enrich soil fertility [41].

Pigeon pea is a perennial legume shrub, 1-4 meters tall. Its leaves have long hairs on the outside and pubescent and green above with a silver grayish green. The flowers are yellow with red to reddish-brown lines and a red outside. Pigeon pea seed takes 2-3 weeks to emerge after sowing. The root system is a deep taproot up to 2 meters in depth. These deep roots help improve water infiltration into the soil [42]. In Africa, subsistence farmers mainly grow it in the semi-arid areas due to its drought tolerance [40]. Globally, it is ranked fifth in production among legumes, after common beans, soybean, cowpeas and chickpeas [43]. Okah *et al.* [44] reported that protein level and carbohydrates of pigeon peas were 18.1 to 31.1 % and ranges from 36 to 66 % respectful.

Pigeon pea grows well on a wide range of well-drained soil types [40] and does not survive waterlogged conditions [45]. Its optimum growth pH ranges 4.5 to 8.0 [46]. Pigeon pea is the most drought tolerant legume, due to its deep rooting systems [47] and can grow at greater than 35 ^oC [45].

Pigeon pea is a good source of protein, rich in amino acids, particularly lysine, methionine and tryptophan, and supplies minerals such as iron, zinc, calcium, potassium and phosphorus [48]. The chemical composition of pigeon pea seed and cow pea are comparable (Table 2).

Table II: Chemical composition of pigeon pea and cow pea

Composition	Pigeon pea seed	Cowpea
crude protein %	21.0	22.77
Ash %	3.2	3.17
Fat %	1.7	2.17
crude fibre %	2.5	4.11
Reference	[49]	[50]

X. Pigeon Pea as Fish Feed

The protein content & its amino acid profile, fibre, mineral, and vitamin composition qualify the Pigeon pea to be a candidate dietary ingredient in both animal and human diets. Hammed *et al.* [51] evaluated effects of partial and total replacement of soybean meal with pigeon pea (*Cajanus cajan*) in diets for juvenile African Mud catfish (*Clarias gariepinus).* The diets were acceptable with growth & feed efficacy of 25% and 100% inclusion of pigeon pea resulted in 23.34 g and 25.47g average weight gain. On food conversion, 0 and 100% inclusion of pigeon pea gave the highest food conversion. Alegbeleye *et al.* [52] evaluated growth performance and nutrient utilization of African Mud Catfish (*Clarias gariepinus*) fingerlings fed different levels of fermented pigeon peas (*Cajanus cajan*) meal. Inclusion of 100% fermented pigeon pea meal did not affect growth performance or nutrient utilization. Ganzon-Naret [53] similarly sustained performance and carcass composition on graded dietary levels of cooked pigeon peas seed meal in diets for Asian sea bass (*Lates calcarifer*). Feeding soaked pigeon peas at 45% dietary inclusion to Nile tilapia (*Oreochromis niloticus L)* fingerlings maintained optimum growth performance and feed utilization in comparison with a commercial fish feed according to Ndau and Madalla [54].

XI. Conclusion

Fish feed accounts for at least 60 % of the total cost of commercial fish production. Protein and energy are the most critical supplements to support fish growth. The scarcity of quality fish feed ingredients is a major constraint to the survival of aquaculture. Local fish feed production is therefore crucial to sustain and develop aquaculture. Agriculture plays an important role in reducing poverty in rural areas and providing a living for more people than any other industry and to quality and affordable fish feed such as pigeon peas would improve fish farming. As fish farming would increase, there will be an improvement in access to animal protein by the population. However, the nutrition and health of the people will also be improved.

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Ralinala Khakhathi Milicent graduated from African Collage of Learning with a Diploma on Office Computer in 2010. She joined the University of Venda in 2011 as an animal science student. She graduated BSC in Agriculture specializing in animal science in 2015. She is currently registered as master’s student in Jilin Agricultural University, China. She has worked as an intern at agricultural research council: germplasm conservation and reproductive biotechnologies in 2018.

Dr F. Fushai (BSc Agriculture, Animal Science, University of Zimbabwe, 1990; MSc Agriculture, Animal Science, University of Kwazulu-Natal, 1996; PhD, Animal Nutrition, University of South Africa, 2014) is an Animal Nutritionist, with research interest and expertise in climate-smart adaptive feeds and livestock feeding strategies.

He is currently a Senior Lecturer and Researcher in Animal Nutrition in the Department of Animal Science at the School of Agriculture, University of Venda, South Africa. He has substantial previous experience in Agricultural Extension as a Livestock and Range Animal Management Specialist in the Department of Agricultural, Technical & Extension in Zimbabwe. He is widely published in accredited Animal Nutrition Journals and International Conferences.

Prof JJ Baloyi graduated with an MSc in Animal Nutrition fron University of Aberdeen (UK) in 1990 and a PhD in Animal Nnutrition at the University of Zimbabwe in 2002. He worked as a Research officer in both ruminat and aquaclture in Zimbabwe before joining the academia at Agricultural colleges (Chibero and Fort Cox) and universities (Zimbabwe Open Universy, North West University, University of South Africa and University of Venda). He was appointed as a Senior lecturer in Animal science departmnet at Unversity of Venda in 2009 and promoted to Associate professor in 2016. He has published a number of scientific manuscripts (33) in referred journals and presented many conference papers (45) at both national and international conferences. He has also succesfully supervised 2 PhD, 16 MSc and 20 Honours students in Animal Science. Prof Baloyi is a member of South African Socoiety of Animal Science (SASAS) and Grassland Society of southern Africa (GSSA). He has also acted as both an external examiner for various universities in and outside Soputh Africa and reviewed a number of manuscripts for publivations in peer reviewed accredited journals. Prof Baloyi was previously awarded awards to study for MSc and short cours in Statistics in the UK, research awards at the University of Venda and lately the Fulbright Research Fellowship to conduct some research at the University of Wyoming in the USA in 2021. Currently Prof Baloyi is the Head of Department of Animal science and the Deputy Dean of the School of Agriculture at the University of Venda.

Prof Jabulani Ray Gumbo graduated with a PhD in Water Resources Management from University of Pretoria in 2007. He was awarded the second-best student poster price at the 12th International Conference on Harmful Algae in 2006 and the study was then published in the prestigious conference proceedings after a rigorous peer review process. This author became a Member (M) of International Society for the Study of Harmful Algae; International Mine Water Association; Water Institute of Southern Africa; Microscopy Society of Southern Africa and South African Council for Natural Scientific Professions. In 2008, he was appointed as a senior lecturer at University of Venda and in 2016 he was appointed as Associate Professor. He is the first or second author of more than 86 research outputs (3 patents, 38 peer reviewed papers with more than thirds of these published in international journals with an impact factor; 41 peer reviewed conference proceedings and 3 technical reports and four book chapters). He acts as a reviewer for NRF in the fields of cyanobacteria and has been invited to be a reviewer for Ohio Sea Grant Proposal (USA); Journal of Applied Phycology (Australia); Bioresource Technology Journal (BITE) (USA); Journal of Freshwater Ecology (Britain); South African Journal of Science (SAJS) (South Africa) and African Journal of Biotechnology (AJB) (Nigeria). He lectures students at undergraduate and postgraduate levels in the fields of water treatment; water quality management; water law and institutions; rural water supply and sanitation; data information systems and water quality principles and he supervises several Honours, Masters and PhD students in the fields of water quality management; aquatic ecotoxicology and limnology and water treatment.