

NUTRIENT EVALUATION OF DIFFERENTLY PROCESSED JUJUBE (*Ziziphus mauritiana* Lam.) FRUIT AS A POTENTIAL FISH FEED INGREDIENT

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ABSTRACT

High cost of fish feed has been a limiting factor for aquaculture development, hence, the needs for continuous research efforts to identify affordable and nutritionally adequate alternative ingredients. This research was carried out to examine the nutritional quality of the raw and processed fruits of Jujube (*Ziziphus mauritiana*) as a potential fish feed ingredient. The Jujube fruits were subjected to different treatments including soaking, boiling, toasting and fermenting following standard methods. The raw and processed fruit meals were then evaluated for proximate, amino acids and fatty acid composition. The results showed that all the processing methods led to increase ash content, crude protein and ether extract. The crude protein was increased from 14.05% in the control (raw) to 17.99 in the fermented *Z. mauritiana*. Toasting led to the better enhancement of the essential amino acids, especially the limiting ones like lysine that was increased to 1.13% from 0.74% in the raw fruit meal powder. Boiling appears to be the best treatment for the non-essential amino acids. Some of the fatty acid compositions were also influenced by the processing methods, fermentation increased Omega 6 fatty acids from 2804.44mg/100g in the control to 3078.47mg/100g. The highest total fatty acid was also reported in the fermentation method. Jujube fruit seed meal has good nutritional quality that could make it suitable as a fish feed ingredient, while toasting and fermentation showed more improvement and they are recommended as the preferred processing methods for enhancement of the nutritional quality of *Z. mauritiana*.

Keywords: *Ziziphus mauritiana*, processing methods, nutritional quality, fish feed, amino acids

INTRODUCTION

Ziziphus mauritiana, a traditional plant in the *Rhamnaceae* family, is also known as the Chinese date (Naaz *et al.*, 2020). Originating in China, it has been used in Traditional Chinese Medicine (TCM) and as a dietary supplement for thousands of years. *Z. mauritiana* is known for its potential to treat various diseases and offers numerous medicinal benefits, including anticancer, antidiabetic, antiulcer, antioxidant, anti-inflammatory, wound healing, and thrombolytic properties, among others. The fruit of jujube was recognized as one of the five most valuable fruits in the *Huangdi Neijing* (475-221 BCE), an ancient Chinese text on herbal medicine (Chen *et al.*, 2017). The fruits are safe for consumption and vary in profile and size. *Z. mauritiana* is also an important forestry species, serving as a multi-purpose tree that provides leaves for fodder, fuel wood, charcoal, and fibres. The plant contains medicinally active compounds such as flavonoids, alkaloids, saponins, and terpenes, contributing to its potency. The rapid global expansion of aquaculture and livestock production suggests a looming crisis in the feed industries, as they struggle to meet the growing demand (FAO, 2024). The aquaculture industry is clearly a significant source of economic gain and employment; however, feed remains the largest production cost, accounting for 60–80% of expenses, with protein being the costliest macro-

nutrient (Hossain and Chakrabaty, 2017; Dasuki *et al.*, 2014). Energy sources are also increasing in cost and any attempt to reduce cost of either of the two most important nutrients, might have significant effect on the cost of production. The cost of fish feed is rising due to competition for raw materials between humans and animals for protein and energy sources (Tacon *et al.*, 2011). In recent years, various alternative plant protein sources have been explored due to the decline in fish meal production and its increasing cost. A promising protein source is derived from plant-based raw materials, including secondary materials such as oilseed meals (Hassan *et al.*, 2018). Among these potential plant ingredients, jujube fruit is a viable option. Thus, there is a need to utilize affordable, readily available plant-based dietary materials to promote growth. The level of inclusion of such ingredients depends on factors like availability, nutrient content, processing techniques, fish species, farming practices, and locality (Gabriel *et al.*, 2007). While plant materials are far cheaper compared to animal feed sources, many of them have burdens of anti-nutritional factors. Scientists have reported various processing techniques that helped in improving the nutritional quality of plant feed sources, some of which include; toasting, soaking, fermentation, boiling, autoclaving among others (Dauda *et al.*, 2023; Hassan *et al.*, 2018) This study examined the nutritional composition of jujube fruits processed

using four different methods, in order to enhance their nutritional quality and see the possibility of inclusion in fish feed.

MATERIALS AND METHODS

Collection and processing of the Jujube fruit

The fruit of *Ziziphus mauritania* was purchased during the month of June, 2024 at *Yar kutungu* market in Katsina Local Government Area of Katsina State, Northern, Nigeria. The fruits were washed, dried and crushed mildly (carefully) in a clean wooden mortar to release the seed. The seeds were dried for better cracking of the woody seed shell, and these seeds and flesh were later crushed into powdered form, further dried for two days then processed using four different processing methods which include fermentation, soaking, boiling and toasting.

Fermentation method; The jujube fruit powder was fermented using yeast fermentation process. The fermentation process was carried out in laboratory following the method of Dauda *et al.* (2023) and Romano *et al.* (2018) with little modifications. Some 5kg of Jujube fruit powder was inoculated with 50g of commercial dry yeast, *Saccharomyces cerevisiae* cell density of 3×10^6 cell g^{-1} , and mixed with distilled water until it homogenized, then it was left to ferment for 48 hrs in an air tight container at 30 to 37°C which is the optimal growth temperature for *S. cerevisiae*. The fermented sample was dried and stored before further analysis.

Soaking method; The jujube fruit powder (5kg) was soaked for 24 hours, then dried. The soaking process was carried out in the laboratory following the method of Kajihaua *et al.* (2014)

Boiling method; The jujube fruit powder (5kg) was boiled for 1 hour, allowed to cool and dried. The boiling process was carried out in laboratory following the method of Onuegbu *et al.* (2013).

Toasting method; The jujube fruit powder (5kg) was toasted for 15mins, allowed to cool and dried. The toasting process was carried out in the laboratory following the method of Wiyeh *et al.* (2023) Harivaindaran *et al.* (2023).

All the processed jujube powder meal were packaged in well labelled polythene bags and taken to laboratory for proximate composition, fatty acid and amino acid profile.

Laboratory analysis

The samples were analyzed (in DM %) for ash content (%), nitrogen (N) content (crude protein = $N \times 6.25$) (%), crude lipid (%), fibre 9%), metabolizable energy (MJ/kg DM) , amino acids are % (g/100g) and fatty acids 9mg/100 g) , using Near-Infrared Reflectance Spectroscopy (NIRS) instrument FSS Forage Analyzer 2500 installed with software package WinISI II the machine is equipped with globally calibrated equations developed by International Livestock Research Institute, Ibadan office, Oyo state, Nigeria. All the analysis was carried out following the standard methods of AOAC (2016).

STATISTICAL ANALYSIS

Data were presented using mean \pm standard deviation, after testing for normality and homogeneity of variance, they were subjected to one way analysis of variance (ANOVA) at 5% level of probability. Tukey's test was used to separate the different means.

RESULTS

The results of the proximate composition are shown in table 1, the dry matter was within the range of 90.15 to 91.51%. It was higher significantly ($P < 0.05$) in fermentation, compared to control and soaking. The highest ash content of $4.87 \pm 0.22\%$ was observed in toasting and it is different significantly ($P < 0.05$) from $3.01 \pm 0.13\%$ in the control. The crude protein was higher significantly in all the treatments than the control ($14.05 \pm 0.11\%$) except in toasting. Among the treatments, fermentation had the highest crude protein of $17.99 \pm 0.54\%$ which was different significantly from toasting and soaking. The highest ether extract of $5.50 \pm 0.26\%$ was observed in the boiling treatment and it was different significantly from soaking and the control. The control had the highest crude fibre of $14.37 \pm 0.28\%$ and it was different significantly ($P < 0.05$) from all other treatments, except toasting. The highest metabolizable energy was recorded in toasting and it is different significantly ($P < 0.05$) from all the other treatments and the control.

Table 1 Proximate composition (%) of raw and differently processed Jujube fruit meal

Proximate composition	Control	Boiling	Toasting	Soaking	Fermenting
Dry matter	90.24±0.01 ^a	90.81±0.30 ^{ab}	90.72±0.02 ^{ab}	90.15±0.62 ^a	91.51±0.03 ^b
Ash	3.01±0.13 ^a	3.40±0.51 ^{ab}	4.87±0.22 ^b	3.81±0.59 ^{ab}	4.12±0.45 ^{ab}
Crude protein	14.05±0.11 ^a	17.09±0.34 ^{cd}	14.49±0.08 ^{ab}	15.79±0.32 ^{bc}	17.99±0.54 ^d
Ether extract	3.85±0.05 ^a	5.50±0.26 ^c	5.31±0.02 ^{bc}	4.65±0.33 ^{ab}	5.39±0.20 ^{bc}
Crude fibre	14.37±0.28 ^c	9.82±0.26 ^b	2.68±0.05 ^a	10.99±0.68 ^b	13.98±0.70 ^c
Metabolizable energy Kcal/kg	9.76±0.04 ^b	9.32±0.04 ^a	10.30±0.09 ^c	9.61±0.03 ^b	9.31±0.02 ^a

Different letters as superscript in each row indicate significant differences (P < 0.05)

The results of the essential amino acid composition are shown in table 2. Histidine was increased in all the processing methods compared to the control. The highest was observed in toasting (0.59±0.00%) and it was different significantly (P<0.05) compared to the control, soaking and fermenting. While arginine was not detected in toasting, it was higher significantly (P<0.05) in all the other treatments compared to the control. Threonine was also higher in all the treatments compared to the control, but it was only higher significantly in toasting (0.92±0.03%). The highest valine (0.94±0.01%) was

observed in toasting and it was different significantly from all other treatments. While the least methionine was recorded in boiling (0.02±0.01%), the highest was in toasting (0.12±0.01%) and it was different significantly (P<0.05) from all other treatments. Lysine was also higher significantly in toasting (1.13±0.00%) compared to all other treatments, a similar result was observed for Isoleucine with the highest in toasting (0.72±0.01%). Leucine and phenylalanine were not different significantly among the treatments.

Table 2: Essential Amino acid composition (%) of raw and differently processed Jujube fruit meal

Amino acids	Control	Boiling	Toasting	Soaking	Fermenting
Histidine	0.47±0.00 ^a	0.55±0.00 ^{bc}	0.59±0.00 ^c	0.52±0.03 ^{ab}	0.53±0.01 ^b
Arginine	0.25±0.01 ^b	0.50±0.85 ^{cd}	0.00±0.00 ^a	0.42±0.03 ^c	0.62±0.01 ^d
Threonine	0.53±0.00 ^a	0.64±0.03 ^a	0.92±0.03 ^b	0.63±0.06 ^a	0.62±0.00 ^a
Valine	0.56±0.01 ^a	0.73±0.01 ^b	0.94±0.01 ^c	0.69±0.04 ^b	0.72±0.01 ^b
Methionine	0.03±0.01 ^{ab}	0.02±0.01 ^a	0.12±0.01 ^c	0.06±0.01 ^b	0.03±0.00 ^{ab}
Lysine	0.74±0.00 ^a	0.94±0.01 ^b	1.13±0.00 ^c	0.92±0.07 ^b	0.67±0.01 ^a
Isoleucine	0.37±0.01 ^a	0.53±0.01 ^c	0.72±0.01 ^d	0.49±0.01 ^c	0.44±0.01 ^b
Leucine	1.47±0.27 ^a	1.23±0.11 ^a	1.36±0.46 ^a	1.11±0.98 ^a	1.16±0.35 ^a
Phenylalanine	0.48±0.21 ^a	0.63±0.03 ^a	0.38±0.07 ^a	0.48±0.07 ^a	0.58±0.35 ^a

Different letters as superscript in each row indicate significant differences (p < 0.05)

The results of the non-essential amino acids composition of the jujube fruit meal are shown in table 3. Boiling had the highest aspartic acid (2.18±0.03%) and it was different significantly (P<0.05) from all other treatments except soaking. Serine was also higher significantly in boiling (0.65±0.00%) compared to the control and toasting. The highest glutamic acid was observed in fermenting (1.71±0.01%) and it was different significantly (P<0.05) from all other treatments except boiling. The highest glycine (0.72±0.04%) was observed in boiling and it was different

significantly from the control and toasting. The highest alanine, proline, cysteine and tyrosine were recorded in toasting (0.97±0.01, 0.76±0.04, 0.38±0.01 and 0.50±0.02% respectively) and they were different significantly (P<0.05) from the control and some of the other treatments. Tryptophan was not different significantly (P>0.05) among the treatments. The highest total amino acid (14.15±0.03%) was in boiling followed by fermenting and it was different significantly (P<0.05) among the treatments.

Table 3: Non-essential Amino acid composition (%) of raw and differently processed Jujube fruit meal

Amino acid	Control	Boiling	Toasting	Soaking	Fermenting
Aspartic	1.67±0.01 ^b	2.18±0.03 ^d	1.24±0.03 ^a	1.95±0.13 ^{cd}	1.92±0.02 ^c
Serine	0.48±0.02 ^b	0.65±0.00 ^c	0.32±0.04 ^a	0.60±0.03 ^c	0.60±0.01 ^c
Glutamic acid	1.18±0.03 ^{ab}	1.53±0.09 ^{cd}	1.00±0.04 ^a	1.35±0.12 ^{bc}	1.71±0.01 ^d
Glycine	0.51±0.01 ^a	0.72±0.04 ^b	0.54±0.04 ^a	0.66±0.02 ^b	0.74±0.00 ^b
Alanine	0.83±0.01 ^a	0.94±0.03 ^c	0.97±0.01 ^c	0.89±0.14 ^b	0.91±0.00 ^{bc}
Proline	0.64±0.01 ^{ab}	0.62±0.01 ^a	0.76±0.04 ^c	0.74±0.04 ^{bc}	0.62±0.01 ^a
Cysteine	0.27±0.01 ^a	0.27±0.01 ^a	0.38±0.01 ^b	0.30±0.04 ^a	0.30±0.00 ^a
Tyrosine	0.21±0.01 ^a	0.27±0.00 ^b	0.50±0.02 ^c	0.26±0.00 ^{ab}	0.30±0.02 ^b
Tryptophan	0.13±0.04 ^a	0.09±0.01 ^a	0.11±0.70 ^a	0.08±0.03 ^a	0.09±0.01 ^a
Total amino acid	11.20±0.11 ^b	14.15±0.03 ^d	10.12±0.01 ^a	13.04±0.24 ^c	13.33±0.07 ^c

Different letters as superscript in each row indicate significant differences ($p < 0.05$)

The results of the fatty acid composition of the jujube fruit meal are shown in table 4. The least Omega 3 fatty acid was observed in the fermenting treatment (380.24±33.18 mg/100g) and it was different significantly ($P < 0.05$) from all other treatments. Omega 6 was not detected in the toasting treatment. The control had the least transfat (3.75±0.29 mg/100g) and it was different significantly ($P < 0.05$) from all the treatments. Saturated fatty acid (Safat), was not detected in the control and fermenting while mono unsaturated fatty acid (Mufat) was not different among the treatments. Both poly unsaturated fatty acid and total fatty acids were lower significantly ($P < 0.05$) in toasting compared to other treatments.

Table 4: Fatty Acids composition of raw and differently processed Jujube fruit meal (mg/100g)

Fatty acid	Control	Boiling	Toasting	Soaking	Fermenting
Omega 3	493.51±16.28 ^b	526.65±0.49 ^b	579.09±18.62 ^b	508.86±26.27 ^b	380.24±33.18 ^a
Omega 6	2804.44±137.04 ^b	2806.18±882.10 ^b	0.000±0.00 ^a	2094.04±84.63 ^b	3078.47±349.28 ^b
Transfat	3.75±0.29 ^a	6.94±0.59 ^b	8.06±0.35 ^b	6.68±1.24 ^b	6.34±0.43 ^b
Saturated fatty acid	0.00±0.00 ^a	344.19±412.29 ^a	63.35±89.59 ^a	229.50±286.81 ^a	0.00±0.00 ^a
Mono unsaturated fatty acid	816.02±154.36 ^a	2354.42±889.08 ^a	3227.45±581.32 ^a	1454.00±1131.20 ^a	2662.31±42.10 ^a
Poly unsaturated fatty acid	3341.70±109.23 ^b	3510.16±994.18 ^b	196.08±277.29 ^a	2699.88±114.36 ^b	2761.62±403.71 ^b
Total Fatty Acid	1026.20±165.92 ^a	3886.40±400.18 ^b	2188.34±71.36 ^a	2332.13±600.76 ^a	3919.05±368.83 ^b

Different letters as superscript in each row indicate significant differences ($p < 0.05$)

DISCUSSION

Protein is the most important nutrient required in fish and it represent the most expensive component of fish feed (Aderolu *et al.*, 2011), the protein content of the *Z. mauritania* fruit can be regarded as high (14.05 – 17.99%) even though it fell below the 20% crude protein content regarded by Rashidi and Barati (2014) as protein-based diet. However, it is above the protein value of most cereal used commercially as energy-based diet. All the experimented processing methods enhanced the protein content of jujube fruit meal with fermentation leading to the best results, this is in line

with the result of Dauda *et al.* (2023) for fermented *Ampelocissus africana* and Hetch 2000) for fermented *Eichhornia crassipes*. Arginine is a semi-essential amino acid that plays a crucial role in nitric oxide synthesis, protein metabolism, and immune function (Salaza-Villanea *et al.*, 2016). The increase in arginine in fermented jujube could be due to the breakdown of proteins and the subsequent release of amino acids. Fermentation in particular could enhance the bioavailability of arginine through enzymatic breakdown of proteins by microbes. Boiling also preserves arginine, likely through minimal denaturation during cooking. Lysine and methionine are limiting amino acids in plant protein.

In this study they are also low, although toasting performed best in enhancing the two limiting amino acids. Lysine is an essential amino acid important for growth, immune function, and calcium absorption. Toasting results in the highest lysine content, likely due to protein concentration. Fermentation appears to reduce lysine content, possibly due to its breakdown by microorganisms during the fermentation process (Dauda *et al.*, 2023). Methionine is an essential sulfur-containing amino acid crucial for protein synthesis and methylation reactions. (Ragab *et al.*, 2010) The slight increase in toasting suggests that heat treatments could concentrate methionine due to reduced moisture, although the relatively low amounts across all methods indicate that this amino acid is less impacted by the processing methods than others. Toasting results in the lowest total amino acid content, this is in line with Akintelu and Amoo (2016). The amino acid profile of the *J. mauritania* fruit meal is very good and better when compared with that of maize, maize bran and cassava (Dasuki *et al.*, 2014, Hejazi *et al.*, 2014) especially for the limiting amino acid in plant protein (lysine, methionine and arginine). The fatty acid profile shows that toasting results in a significant increase in omega-3 fatty acids, which may be due to the concentration of omega-3s during the loss of moisture in the toasting process. However, fermenting shows a decrease, which could be attributed to the breakdown of omega-3s by microbial activity during fermentation. Fermentation could also potentially change polyunsaturated fatty acids (PUFAs) due to enzymatic actions (Afify *et al.*, 2012). The drop to zero in toasting could indicate the loss of omega-6 fatty acids due to high-temperature exposure, possibly through oxidation or degradation. Boiling, soaking and fermenting enhanced omega-6 levels, likely due to the water-based processes that protect against degradation (Borowiec and Michalak, 2022). MuFat and PuFat were not enhanced by the processing methods, while fermentation led to the highest total amino acids.

CONCLUSION

The research revealed that jujube fruit meal is an ingredient with high protein content beyond an average energy-based diet but it is not sufficient to be classified as protein-based diet. It also has good amino acids and fatty acids composition that compared better than an average cereal used as energy source. The nutritional quality was enhanced at various levels by the different processing method, however, fermenting and toasting appeared to be the best among the processing methods. They are therefore recommended for inclusion in fish diet and experimented for performance of different fish species to establish their potentials as fish feed ingredient.

REFERENCES

- Aderolu, A. Z., Aarode, O. O., and Adigun, A. (2011). Replacement of maize with graded levels of noodle waste in commercial diet of African catfish. *Nigerian Journal of Fisheries*, 8(2), 265-271.
- Afify, A. E.-M. M., EL-beltagi, H. S., Abd EL-Salam, S. M., and Omran, A. A. (2012). Oil and Fatty Acid Contents of White Sorghum Varieties under Soaking, Cooking, Germination and Fermentation Processing for Improving Cereal Quality. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, 40(1), 86–92. <https://doi.org/10.15835/nbha4017585>
- Akintelu, M. T., and Amoo, I. A. (2016). Proximate characterisation and physicochemical properties of raw and boiled milk bush (*Thevetia peruviana*) seed. *International Journal of Science*, 5(3), 16-21.
- AOAC. (2016): Official Methods of Analysis of Association of Official Analytical Chemists AOAC International. *Association of Official Analytical Chemists, 20th Edition*, Arlington, Virginia, USA.
- Borowiec, K., and Michalak, A. (2022). Flavonoids from edible fruits as therapeutic agents in neuroinflammation—a comprehensive review and update. *Critical Reviews in Food Science and Nutrition*, 62(24), 6742-6760.
- Chen, J., Liu, X., Li, Z., Qi, A., Yao, P., Zhou, Z., and Tsim, K. W. (2017). A review of dietary *Ziziphus jujuba* fruit (Jujube): Developing health food supplements for brain protection. *Evidence-Based Complementary and Alternative Medicine*, 2017(1), 3019568.
- Dasuki, A., Dauda, A.B and Oshoke, J. O (2014). Preliminary Investigation of Nutritional Quality of *Senna Obtusifolia* for Potential Use in Fish Feed. *American-Eurasian Journal of Sustainable Agriculture*, 8(5), 94-98. <http://www.aensiweb.com/AEJSA>.
- Dauda, A.B.1, Isah, M.M.1, Nasir, B., Abdulrahman, K, Echuo-Odu, C. A. , Ismail, Q. O. , Abdurrasheed, N. , Salele, H.A and H. O. Abdulkareem. Fermentation enhance the quality of wild grape (*Ampelocissus africana*) leaf meal: A potential ingredient in fish diet formulation. In: Lelei K.E. (Edited) Book of Proceedings of the 38th Annual Conference of the Fisheries Society of Nigeria, held at the Niger Delta University, Faculty of Law, Ovon, Yenagoa, Bayelsa State, Nigeria. 27th November – 1st December, 2023. Pp 488 - 492.

- FAO. 2024. The State of World Fisheries and Aquaculture 2024 – Blue Transformation in action. Rome. <https://doi.org/10.4060/cd0683en>
- Gabriel, U. U., Akinrotimi, O. A., Bekibele, D. O., Onunkwo, D. N., and Anyanwu, P. E. (2007). Locally produced fish feed: potentials for aquaculture development in sub-Saharan Africa. *African Journal of Agricultural Research*, 2(7), 287-295.
- Harivaindaran, K. V., Hữu Tiên, N., Nguyễn Song Đình, T., Samsudin, H., Ariffin, F., and Mohammadi Nafchi, A. (2023). The effects of superheated steam roasting on proximate analysis, antioxidant activity, and oil quality of black seed (*Nigella sativa*). *Food Science & Nutrition*, 11(11), 7296-7310.
- Hassaan, M. S., Soltan, M. A., Mohammady, E. Y., Elashry, M. A., El-Haroun, E. R. and Davies, S. J. (2018). Growth and physiological responses of Nile tilapia, *Oreochromis niloticus* fed dietary fermented Sunflower meal inoculated with *Saccharomyces cerevisiae* and *Bacillus subtilis*. *Aquaculture*, 495:592- 601.
- Hejazi, S. M., Abrishami, L. H., and Ashkanifar, M. (2014). The impact of aerobic selected exercises on some of the inflammatory cardiovascular factors in type II diabetics. *Adv. Environ. Biol.*, 8(9): 357-362
- Hetch, T., (2000). Consideration on African Aquaculture. *J. World Aquaculture*. 31, 12-19.
- Hossain, M. M., and Chakraborty, S. C. (2017). Growth and economic analysis of freshwater prawn, *Macrobrachium rosenbergii* (de Man), produced with feeds substituting sunflower cake for fish meal, soyabean meal and mustard oil cake. *Aquaculture Research*, 48(10), 5418-5429.
- Kajihaua, O. E., Fasasi, R. A., and Atolagbe, Y. M. (2014). Effect of different soaking time and boiling on the proximate composition and functional properties of sprouted sesame seed flour. *Nigerian Food Journal*, 32(2), 8-15.
- Naaz, F., Agari, N., and Singh, A. (2020). Medicinal Properties of *Ziziphus mauritiana*: A Review Article. *Int. J. Pharm. Pharm. Res*, 19, 219-230.
- Onuegbu, N. C., Nworah, K. O., Essien, P. E., Nwosu, J. N. and Ojukwu, M. (2013). Proximate, functional and antinutritional properties of boiled Ukpo seed (*Mucuna flagellipes*) flour. *Nigerian Food Journal* 31 (1): 1 – 5.
- Ragab, H. I., Kijora, C., Ati, K. A., and Danier, J. (2010). Effect of traditional processing on the nutritional value of some legumes seeds produced in Sudan for poultry feeding. *International Journal of poultry science*, 9(2), 198-204.
- Rashidi, S. F., and Barati, R. (2014). On the comparison of supply chain with Sub-Dm in Dea. *Advances in Environmental Biology*, 8(7), 2387-2390.
- Romano, N., Dauda, A.B., Ikhsan, N., Karim, M. and Kamarudin, M.S. (2018). Fermenting rice bran as a carbon source for biofloc technology improved the water quality, growth, feeding efficiencies, and biochemical composition of African Catfish, *Clarias gariepinus* juveniles. *Aquac. Res.*, 49(12):3691-3701. <https://doi.org/10.1111/are.13837>
- Salazar-Villanea, S., Bruininx, E. M., Gruppen, H., Hendriks, W. H., Carré, P., Quinsac, A., and van der Poel, A. F. (2016). Physical and chemical changes of rapeseed meal proteins during toasting and their effects on in vitro digestibility. *Journal of Animal Science and Biotechnology*, 7, 1-11.
- Tacon, A. G., Hasan, M. R., and Metian, M. (2011). Demand and supply of feed ingredients for farmed fish and crustaceans: trends and prospects. *FAO Fisheries and Aquaculture technical paper*, (564), I.