FUDMA Journal of Sciences (FJS)
ISSN online: 2616-1370
ISSN print: 2645 - 2944
Vol. 9 April Special Issue, 2025, pp 327 - 331
DOI: https://doi.org/10.33003/fjs-2025-09(AHBSI)-3602

INFLUENCE OF PROCESSING METHODS ON THE PHYTOCHEMICAL, MINERAL AND FIBRE FRACTION OF JUJUBE FRUIT MEAL AS A POTENTIAL FISH FEED INGREDIENT

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ABSTRACT

Most of the ingredients used in fish feed preparation are extremely competitive since they are eaten by man and utilized in agro allied industry, hence costly. Consequently, effort concerning using plant materials that are not used by man received less attention. *Ziziphus mauritiana* is a common fruit that is found widely in numerous regions of the world. Hence this study examined some nutritional characteristics of raw and differently processed *Z. mauritiana* fruit meal as a potential ingredient in fish feed preparation. The fruit meal was processed by boiling, toasting, soaking and fermenting using standard methods. The processed meals were examined in triplicates for phytochemicals, minerals and fibre fractions. The results revealed that alkaloid was reduced significantly in boiling by 66.22% while toasting reduced the tannin level significantly ($P<0.05$) compared to fermenting. Flavonoid was increased significantly in boiling and fermenting. Toasting also showed superior performance in mineral content by significantly ($P<0.05$) reduced sodium and increased calcium, magnesium, potassium and iron. The fibre fractions were also varied among the processing methods. The highest Ndf (41.43±0.89%) was observed in toasting, so also the highest Ivomd (71.55±0.09%) and they were different significantly from other treatments. The least Adl (lignin) was also recorded in toasting (2.41±0.33%) and it was different significantly from all other treatments. The study established that all the processing methods influenced the Jujube fruit meal, however, toasting conferred the highest positivity. A feeding trial with inclusion of the processed Jujube fruit meal is therefore recommended.

Keywords: Fibre fraction, Phytochemical, Processing methods, Jujube fruit

INTRODUCTION

The high cost of fish feed has been continuously established as a major constraint to the development of fish production in Nigeria (Dauda *et al*., 2015; Dauda *et al*., 2023) and in other parts of the world. This has spurred scientists globally to attempt experimental trials on potential plants and animal materials that could be available at a cheap cost, in order to reduce cost of fish feed and hence, ensuring reduction in the price of farmed fish. Several neglected plants and those that are not directly consumed by man has been experimented and found promising (Okomoda *et al.*, 2022), this include *Jatropha curcass*, *Mucuna pruriens*, *Ipeoma batatas* among others. The jujube (*Ziziphus mauritiana lam*.), a member of the *Rhamnaceae* family, consists of approximately 170 species and 12 varieties in the Ziziphus genus worldwide (Xu *et al*., 2022). Cultivated jujube was domesticated originally from wild jujube in the middle and lower drainages of the Yellow River in China (Xu *et al*., 2022). The fruit contains a high level of sugars and is rich in vitamin C, iron, and calcium (Rashwan *et al*., 2020; Xu *et al*., 2022). It also contains active substances such as polyphenols, polysaccharides, and trienoic acid (Shi *et al*., 2022), which have been proven to be beneficial. The plant contains has a fair protein content with good amino acids composition (Yakubu *et al.*,2024). Jujube is reported to have a high nutritional value, and its production has earned substantial income for farmers in recent years (Xu *et al*., 2022).

Jujube is palatable and is high in sugar content and energy yield but low in protein content, and therefore, it could be used as a high-energy feed. The concentrations of calcium and phosphorus vary greatly. In livestock, poultry, and fish, the proper level of jujube as a supplement or as a replacement can increase feed palatability, feed intake, and nutrient digestibility, reduce the feed-to-gain conversion rate and improve the intestinal microbial system and quality of animal products (Xu *et al*., 2022). Compared with other fruits, fresh jujube is lower in water content, but higher in soluble solids, phenolics and ascorbic acid (Kader, 2000).

Many factors impact fruits quality, including appearance, colour, texture and flavour, an equally important quality which is invisible is the nutritional quality. An increasingly important aspect of nutritional quality is the content of phytochemicals, which are responsible for health protection and disease prevention. The phytochemical content of fruit tissues is influenced by numerous pre-harvest factors, including genotype, rootstock, climatic conditions, agronomic practices and harvesting time, and also by postharvest factors, including storage conditions and processing procedures (Cevallos- Casals *et al*., 2006). The interest in the consumption of fruits has been boosted because of increased awareness of their possible health benefits. Phytochemicals in fruits such as phenolic acids, flavonoids, ascorbic acid, and carotenoids are strong antioxidants and could confer health benefits on fish, it it is included in their diets. These compounds are gaining increased attention because of their many health-promoting functions like antioxidants, antiaging, antidiabetics, antiinflammatory, etc. (Islam *et al*., 2021). A progressive increase in scientific publications on phytochemicals strongly recommends the consumption of phytochemical-rich food for the control of degenerative diseases like cancer, diabetics, and cardiovascular diseases. Therefore, research in the investigation of phytochemical compounds and their functional properties on fruits and vegetables has increased significantly over the last few years (Islam *et al*., 2021).

Research on the nutritional components and active substances of jujube has increased, and the use of jujube as a feed additive or replacement has received increasing attention (Xu *et al*., 2022). However, the anti-nutritional contents of some of these fruits may interfere with the metabolic process and thus limit nutrient bioavailability by the body when consumed (Alawode *et al*., 2021), especially for single stomach organisms like fish. Therefore, this study was carried out to assess the phytochemical, mineral and fibre fraction compositions of jujube fruits grown in Katsina state, Nigeria as a potential ingredient in fish feed.

MATERIALS AND METHODS

Collection and treatment of samples

The collection and processing were carried out as described in our previous study (Yakubu *et al*., 2024). Dry fruits of *Z. mauritiana* were purchased in a local market in Katsina, 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 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 x 106 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^{0}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 Kajihausa *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).

All the processed jujube powder meal were packaged in well labelled polythene bags and stored in a refrigerator before taken for laboratory analysis.

Laboratory analysis

The samples were analyzed for minerals and fibre fraction 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. Phytochemical analysis was carried out at the Institute of Agricultural Research, Ahmadu Bello University Zaria. All the analysis was carried out following the standard methods of AOAC (2016).

Statistical analysis

Data for phytochemicals, minerals and fibre fractions were presented using mean±standard error. After testing for normality and homogeneity of variance, they were subjected to one way analysis of variance (ANOVA) at 95% level of probability ($P<0.05$) to compare performance among the different treatment methods. Tukey's test was used to separate the different means. The analysis was done using IBM SPSS version 27.

RESULTS AND DISCUSSION

The results of the phytochemical composition are shown in Table 1. All the processing methods significantly ($P<0.05$) reduced the alkaloid except toasting that led to increase in the alkaloid content. The highest reduction (66.22%) was observed in boiling where the alkaloid was reduced from 2.28±0.04% in the raw to 0.77±0.13%. All the processing methods led to increase in tannin except toasting where it was reduced to 0.58±0.25% compared to 1.25±0.14% in the raw, although the difference was not significant ($P>0.05$) with the raw but it was with fermenting. Phytate, oxalate and saponin were not different significantly among the treatments ($P>0.05$). Flavonoid was increased significantly ($P<0.05$) in the boiling (45.13±6.26%) and fermenting (46.53±4.35%) compared to the raw jujube fruit meal (26.45±4.45%).

Table 1: Phytochemical composition (%) of raw and differently processed Jujube fruit

	Raw	Boiling	Toasting	Soaking	fermenting
Alkaloid	2.28±0.04b^{c}	0.77±0.13^{a}	3.05±0.44^{c}	1.77±0.41^{ab}	1.49±0.13^{ab}
Tannin	1.25±0.14^{ab}	1.53±0.32^{ab}	0.58±0.25^{a}	1.60±0.49^{ab}	2.75±0.57^{b}
Phytate	0.14±0.03^{a}	0.14±0.03^{a}	0.11±0.02^{a}	0.11±0.02^{a}	0.14±0.03^{a}
Oxalate	0.07±0.01^{a}	0.07±0.01^{a}	0.06±0.00^{a}	0.07±0.01^{a}	0.07±0.01^{a}
Saponin	11.58±1.87^{a}	9.08±0.25^{a}	10.05±1.84^{a}	17.15±4.17^{a}	11.65±1.63^{a}
Flavonoid	26.45±4.45^{a}	45.13±6.26^{b}	41.48±1.38^{ab}	33.45±3.18^{ab}	46.53±4.35^{b}

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

Table 2, shows the mineral composition of raw and differently processed Jujube fruit where all the processing methods increased sodium content except toasting where it was lowered significantly ($P<0.05$) compared to others. Toasting significantly ($p<0.05$) increased potassium content 21088.18±170.26 mg/100g, followed by fermenting 14510.47±739.10 mg/100g. Significantly higher ($P<0.05$) calcium (14069.90±467.57 mg/100g), magnesium (14069.90±467.57 mg/100g) and iron (1580.62±61.94 mg/100) were also observed in toasting compared to other processing methods.

Table 2: Mineral composition (mg/100g) of raw and differently processed Jujube fruit

	Raw	Boiling	Toasting	Soaking	fermenting
Sodium	2870.96±112.91[b]	3483.61±27.12[d]	2391.38±0.91[a]	3150.24±104.48[bc]	3272.15±11.74[cd]
Potassium	9318.08±114.78[a]	10774.54±298.90[a]	21088.18±170.26[c]	9785.56±359.03[a]	14510.47±739.10[b]
Magnesium	2812.47±48.85[a]	4076.29±190.35[c]	8741.54±135.71[d]	3566.94±17.45[b]	3328.35±27.53[b]
Calcium	6699.10±12.67[a]	7544.55±275.16[a]	14069.90±467.57[b]	7520.27±1073.42[a]	6363.83±1012.97[a]
Manganese	199.46±5.15[ab]	229.90±14.98[bc]	172.37±4.09[a]	240.62±12.46[c]	183.88±6.14[a]
Ferric	837.40±40.33[a]	1196.60±58.78[a]	1580.62±61.94[b]	1145.96±183.44[a]	1105.75±1.15[a]
Copper	10.75±0.30[a]	14.90±0.37[cd]	13.74±0.33[bc]	13.12±0.49[b]	15.29±0.30[d]
Zinc	53.88±1.36[ab]	59.58±3.06[bc]	57.410±0.85[abc]	61.74±1.73[c]	51.94±0.33[a]
Phosphorus	6817.03±0.00[a]	6817.03±0.00[a]	6817.03±0.00[a]	6817.03±0.00[a]	6817.03±0.00[a]

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

Table 3 shows the fibre fractions of raw and processed jujube fruit meal. Toasting and raw had the lowest Neutral dry matter, while boiling (2.74±0.05%) and fermenting (2.88±0.08%) increased Neutral dry matter significantly ($P<0.05$). Ndf was higher significantly ($P<0.05$) in toasting (41.43±0.89%) compare to the raw and other methods. Adf was not different significantly ($P>0.05$) among the treatments. Toasting significantly reduced lignin (2.41±0.33%) and improved digestibility (71.55±0.09%) while boiling increased lignin (6.22±0.13%). Gas 24 was significantly higher in the raw (53.66±0.53%) compared to all the processing methods except soaking, while the least was observed in toasting (47.18±0.74%). The highest (71.55±0.09 %) in vitro organic matter digestibility was observed in toasting and it different significantly from all other treatments.

Table 3: Fibre fraction (% of dry matter) of raw and differently processed Jujube fruit

	Raw	Boiling	Toasting	Soaking	fermenting
Ndm	2.25±0.01[a]	2.74±0.05[c]	2.32±0.01[a]	2.53±0.05[b]	2.88±0.08[c]
Ndf	35.42±0.35[a]	34.02±1.20[a]	41.43±0.89[b]	32.98±0.20[a]	34.18±0.54[a]
Adf	11.47±0.28[a]	11.19±0.82[a]	10.93±0.93[a]	9.69±0.53[a]	10.78±0.18[a]
Adl	5.18±0.01[b]	6.22±0.13[c]	2.41±0.33[a]	5.31±0.30[b]	5.99±0.08[bc]
Gas24	53.66±0.53[c]	49.37±0.21[ab]	47.18±0.74[a]	51.72±0.47[bc]	49.01±1.15[ab]
Ivomd	68.64±0.33[a]	67.60±0.8[a]	71.55±0.09[b]	68.89±0.57[a]	67.84±0.44[a]

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

KEY- Ndm (Neutral dry matter), Ndf (Neutral Detergent Fibre), Adf (Acid detergent fibre), Adl (Acid detergent lignin), Gas24 (Gas production after 24 hours), Ivomd (In vitro organic matter digestibility)

Discussion

Carbohydrates represent the cheapest source of dietary energy, and hence, hence are included in diets matching to the maximum tolerance level of the target fish so as to spare more expensive dietary proteins from being utilized for energy production. Accordingly, dietary carbohydrates are usually quantitatively the largest constituent of diet 40-55% (Kumar et al.,2018). The alkaloid recorded in this research was reduced by processing except in toasting. This shows positivity because too much alkaloid in fish feed have been shown to affect nerve function and can be toxic to fish, the bitterness of these alkaloids may lead to decreased feed intake as reported by Hemre et al. (2009)

Njidda and Olatunji (2012) stated that the ultimate effect of high condensed tannin concentration is to make the animal both energy and protein deficient, which thereby leads to reduced growth or weight loss and poor reproduction. The tannins recorded in this research was within the range of 0.58-2.75% which was higher than the 0.38% documented by Njidda and Olatunji (2012) and 0.28% by Gidado et al. (2013), toasting however reduced compared to the raw and other methods. Flavonoid showed an increase after processing but is within moderate safe range reported by Zahran et al. (2018), who concluded that high flavonoid could lead to reduced feed intake or interfere with nutrient absorption due to protein/flavonoid binding. The concentrations of sodium, potassium, content of *Z. mauritiana* raw and processed Jujube fruit meal were appreciably higher but within normal range as previously noted by Monire *et al*. (2025) that growth performance in Nile tilapia improves significantly with the rise of NaCl levels in the diets up to 10 g/kg feed. Beyond this point, growth performance declined. Overall mineral content revealed toasting as the best treatment, as it reduced the sodium and increased calcium, magnesium and iron. The results of fibre fractions further confirmed superiority of toasting as it significantly improves Ndf while reducing lignin content. It also led to the highest Ivomd, making it a promising processing method for enhancing quality of Jujube fruit meal. Similar findings were reported by Mwenya et al. (2005), who observed that thermal treatments such as toasting reduce lignin content and improve digestibility by disrupting cell wall structures. However, fermentation increased adl, which may limit its long-term digestibility benefits. This is consistent with reports by Babayemi et al. (2004), who noted that fermentation can increase lignin content in some feed materials. Soaking had minimal impact on most parameters, which may be attributed to the limited effect of water treatment on cell wall structure and lignin degradation (Makkar, 2003). This aligns with findings by Mahala & Khalifa (2007), who noted that soaking alone does not significantly affect fiber or lignin content. Boiling, while enhancing Ndm content, had a similar effect on ivomd as the control, suggesting its limited ability to improve digestibility. The increased adl in boiled samples indicates that prolonged heating may lead to the concentration of lignin and fiber components (Babayemi et al., 2004).

CONCLUSION

The results of the research showed that all the experimented processing methods applied on the Jujube fruit meal have varying influences on the fiber, minerals and phytochemicals. However, toasting led to a superior performance as it lowered the tannin, decreased sodium, increase calcium, potassium, magnesium and iron. It also led to a reduction in lignin and increased in vitro organic matter digestibility. It is therefore recommended Jujube processed with the different methods should be fed to fish to see the actual performance as a fish feed ingredient

ACKNOWLEDGEMENT
The authors would like to appreciate the TETFund and the management of Federal University for funding this research though Institutional Based Research Grant.

REFERENCES

Akinsola, R.O., Abubakar, E & Zaina, A. (2016). Proximate and Phytochemical analysis of *Ziziphus Mauritiana lam* leaf. *Frontier in Biomedical Science*, 2(1), 45.49.

Alawode, A.R., Ndamitso, M.M., Iyaka, A.Y., & Anuonye, C.J., (2021). Effects of fermentation on the proximate, antinutrients, minerals, fatty acids, and amino acids profiles of jujube (*Ziziphus mauritianaLam*) seeds. *AROC in Food and Nutrition*, 1(1), 31-40, https://doi.org/10.53858/arocfn01013140

AOAC, 2005. Official Methods of Analysis of AOAC International,18th edition, Association of Official Analytical Chemists, Gaithersburg, MD

AOAC, 2006. Official Methods of Analysis. Official Method 982.30 E (a), Chp. 45.3.05, acid hydrolysis. 23rd ed. Association of Official Analytical Chemists, Gaithersburg, MD.

Azim A, Ghazanfar, S, Latif, A. & Nadeem, M.A (2011).Nutritional evaluation of some top fodder tree leaves and shrubs od District Chakwai, Pakistan in relation to Ruminants Requirements, *Pakistan Journal of Nutration*, 10(1), 54-59.

Babayemi, O. J., Demeyer, D., & Fievez, V. (2004). Nutritive value and qualitative assessment of a variety of maize stover in West Africa. *Animal Feed Science and Technology*, 119(1-2), 25–34.

Cevallos-Casals, B.A., Byrne, D., Okie, W.R., and Cisneros-Zevallos, L. 2006. Selecting new peach and plum genotypes rich in phenolic compounds and enhanced functional properties. *Food Chem*. 96(2):273–280.

Cevallos-Casals, B. A., Byrne, D., Okie, W. R., & Cisneros-Zevallos, L. (2006). Selecting new peach and plum genotypes rich in phenolic compounds and enhanced functional properties. *Food chemistry*, *96*(2), 273-280.

Dasuki, A, Dauda , A.B & Oshoke, J. O (2014). Preliminary Investigation of Nutritional Quality of Senna Obtusifolia for Potential Use in Fish Feed. *American-Eurasian Journal of Sustainable Agriculture*ISSN: 1995-0748, JOURNAL home page: http://www.aensiweb.com/AEJSA 2014 April; 8(5): pages 94-98.

Dauda, A. B., Dasuki, A., & Bichi, A. M. H. (2015). Analysis of constraints to aquaculture development in Sudano-Sahelian region of Nigeria. *Tropical and subtropical agroecosystems*, *18*(2).

Dauda, A. B., Dasuki, A., Oshoke, J. O., Nababa, A. S., & Bello, O. M. (2023). Status of Fish Farming in Katsina State, Nigeria: The Current Practices, Operation, Management and Constraints to its Development. *FUDMA Journal of Agriculture and Agricultural Technology*, *9*(4), 9-17.

Elghandour, M. M. Y., et al. (2018). In vitro gas production and ruminal fermentation of fermented total mixed rations. *Journal of Dairy Science*, 101(1), 202–212.

Esenwah, CN and Ikenebomeh, MJ. 2008. Processing effects on the nutritional and anti-nutritional contents of African locust bean. Parkia biglobosaBenth. Seed. Pak. *J Nut*. ,7. 2., pp 214-217

Getachew, G., Makkar, H. P. S., & Becker, K. (2004). In vitro gas measuring techniques for assessment of nutritional quality of feeds: A review. *Animal Feed Science and Technology*, 123–124, 21–34.

Gidado, O. G,. Kibon, A,. Gwargwor, Z.A,. Mbaya, P.A & Baba, M.J (2013). Assessment of antinutitive value and nutrient composition of some selected browse plants use as livestock feeds in Taraba State. *International Journal of Applied Sciences Engineering*, 1(1), 5-9.

Hemre, G. I., Ringø, E., Amlund, H., Aursand, M., Bakke-McKellep, A. M., Olsen, R. E., & Svihus, B. (2009). Criteria for safe use of plant ingredients in diets for aquacultured fish.

Hoseinifar, S.H.; Khodadadian Zou, H.; Van Doan, H.; Harikrishnan, R.; Yousefi, M.; Paknejad, H.; Ahmadifar, E. Can dietaryjujube (*Ziziphus jujuba Mill.)* fruit extract alter cutaneous mucosal immunity, immune related genes expression in skin and growthperformance of common carp (Cyprinus carpio)? *Fish Shellfish Immunol*. 2019, 94, 705–710. [CrossRef]

Ijarotimi O.S., Keshinro O.O., (2012). Comparison between the amino acid, fatty acid, mineral and nutritional quality of raw, germi- nated and fermented African locust bean (Parkia biglobosa) flour. *Acta Sci. Pol., Technol. Aliment*. 11(2), 151-165

Ijarotimi OS (2012). Influence of germination and fermentation on chemical composition, protein quality and physical properties of wheat flour (Triticum aestivum. J Cer.Oil seeds, 3(3), pp. 35-47

Islam M.R., A.R. Haque, M.R. Kabir, M.M. Hasan, K.J. Khushe, S.M.K. Hasan, Fruit by-products: the potential natural sources of antioxidants and α-glucosidase inhibitors, *J. Food Sci. Technol.* 58 (2021) 1715–1726.

Johnstone, R. M., & Shan, F. (2014, August). Chinese jujube industry takes root in Western Australia. In *XXIX International Horticultural Congress on Horticulture: Sustaining Lives, Livelihoods and Landscapes (IHC2014): III 1116* (pp. 31-34).

Kumar, M., Patel, A. B., Keer, N. R., Mandal, S. C., Biswas, P., & Das, S. (2018). Utilization of unconventional dietary energy source of local origin in aquaculture: Impact of replacement of dietary corn with tapioca on physical properties of extruded fish feed. *Journal of Entomology and Zoology Studies*, *6*(2), 2324-2329.

Li, J.W., Fan, L.P., Ding, S.D. & Ding, X.L. 2007. Nutritional composition of five cultivars of Chinese jujube. *Food Chem. 103* (2):454-460.

Mahala, A. G., & Khalifa, H. (2007). Effect of different treatments on chemical composition and in vitro digestibility of some common feed resources. *Research Journal of Agriculture and Biological Sciences*, 3(6), 1026–1029.

Makkar, H. P. S. (2003). Quantification of tannins in tree foliage*: A laboratory manual*. Kluwer Academic Publishers.

Mbah, G. O., Onyeabo, U. A., & Udeh, B. C. (2018). Effect of fermentation on nutritional composition of African oil bean seed. *The Pacific Journal of Science and Technology*, *19*(1), 244-250.

Monier, M. N., Abd El-Naby, A. S., Fawzy, R. M., Samir, F., Shady, S. H., Grana, Y. S., ... & Abdel-Tawwab, M. (2025). Growth performance, antioxidant, and immune responses of Nile tilapia (Oreochromis niloticus) fed on low-fishmeal diets enriched with sodium chloride and its adaptability to different salinity levels. *Fish Physiology and Biochemistry*, *51*(1), 6.

Morton, J.F (1987). Indean jujube in: Morton, J.F (Ed). Fruit of warm climates, Miami, Floriada, 272-275

Mwenya, B., Santoso, B., Sar, C., Pen, B., Morikawa, R., Takaura, K., Umetsu, K., Kimura, K. & Takahashi, J. (2005). Effects of yeast culture and galacto-oligosaccharides on ruminal fermentation in Holstein cows. *Journal of Dairy Science*, *88*(4), 1404-1412.

Ndidi, U. S., Ndidi, C. U., Olagunju, A., Muhammad, A., Billy, F. G., & Okpe, O. (2014). Proximate, antinutrients and mineral composition of raw and processed (Boiled and Roasted) Sphenostylis stenocarpa seeds from Southern Kaduna, Northwest Nigeria. *International Scholarly Research Notices*, *2014*(1), 280837.

Njidda, A.A & Olatunji, E. A (2012). Chemical Compositions, Anti-nutritive Substances and In situ Digestion Kinetic of Flour Ziziphus Leaves use as Fodder for Ruminants in Semi-arid zone of Nigeria, *Journal of Natural Sciences Research*, 2(7),79-87

Nwokolo, E, (1987). "A nutritional assessment of African yam bean Sphenostylis stenocarpa. Hoechst ex A Rich. Harms and Bambara groundnut. *J Sci. Food and Agric*. 41, 2, 123–129.

Okello, J. (2010). Morphological and nutritional characteristics of Tamarindus indica (Linn) fruits in Uganda. *Unpublished master's thesis, Makerere University, Uganda*.

Okomoda V. T., Musa S. O., Tiamiyu L. O., Solomon S. G., Adeyemo B. T., Alamanjo C. C. & Abol-Munafi A. B. (2022). Dietary implications of toasted *Jatropha curcas* seed: Insight on zootechnical and hematological parameters of *Clarias gariepinus*. *Comparative Clinical Pathology* 31: 81–90

Oluseyi EO, & Oyesiku TO. (2015). "Chemical and functional properties of fermented, roasted and germinated tamarind. Tamarindus indica. seed flours*", Nutrition & Food Sci. 45, 1, 97-111,*

Orwa, C. (2009). Agroforestree Database: a tree reference and selection guide, version 4.0. *http://www. worldagroforestry. org/sites/treedbs/treedatabases. asp*.

Osman, MA. (2007). Effect of different processing methods on nutrient composition, antinutritional factors and in vitro protein digestibility of Dolichos lablab bean [Lablab purpuresus. L. Sweet *Pakistan Journal of Nutrition*, 6, pp299-303

Rani, S., Poswal, G., Yadav, R., & Deen, M. K. (2014). Screening of pigeon pea (Cajanus cajan L.) seeds for study of their flavonoids, total phenolic content and antioxidant properties. *International Journal of Pharmaceutical Sciences Review and Research*, *28*(2), 90-94.

Rashwan, A. K., Karim, N., Shishir, M. R. I., Bao, T., Lu, Y., & Chen, W. (2020). Jujube fruit: A potential nutritious fruit for the development of functional food products. *Journal of Functional Foods*, *75*, 104205.

Schiere, J. B., Ibrahim, M. N. M., & Van Keulen, H. (2004). The role of livestock for sustainability in mixed farming: Criteria and scenario studies under varying resource allocation. *Agricultural Systems*, 79(2), 183–208.

Shi, Q., Han, G., Liu, Y., Jiang, J., Jia, Y., & Li, X. (2022). Nutrient composition and quality traits of dried jujube fruits in seven producing areas based on metabolomics analysis. *Food Chemistry*, *385*, 132627.

Shi, Q., Han, G., Liu, Y., Jiang, J., Jia, Y., & Li, X. (2022). Nutrient composition and quality traits of dried jujube fruits in seven producing areas based on metabolomics analysis. *Food Chemistry*, *385*, 132627.

Temple, V. J., Odewumi, L., & Joseph, K. (1991, August). Soybeans and soybean based diets. In *Proceedings of the 3rd Regional Workshop on Rural Development* (pp. 45-50).

Van Soest, P. J. (1994). *Nutritional Ecology of the Ruminant*. Cornell University Press.

Xu, T., Zhou, X., Degen, A., Yin, J., Zhang, S., & Chen, N. (2022). The inclusion of jujube by-products in animal feed: A review. *Sustainability*, *14*(13), 7882.

Yakubu H.B., Bichi A.H. and Dauda A.B. (2024). Nutrient Evaluation of Differently Processed Jujube (*Ziziphus Mauritiana Lam.)* Fruit as a Potential Fish Feed Ingredient. *Nigerian Journal of Fisheries*, 21(2), 3057-3062.

Yerima, B. I., & Adamu, H. M. (2011). Proximate chemical analysis of nutritive contents of Jujube (Ziziphus mauritiana) seeds. *International Journal of the Physical Sciences*, *6*(36), 8079-8082.

Zahran, E., Abd El-Gawad, E. A., & Risha, E. (2018). Dietary Withania sominefera root confers protective and immunotherapeutic effects against Aeromonas hydrophila infection in Nile tilapia (Oreochromis niloticus). *Fish & Shellfish Immunology*, *80*, 641-650.

Zhang, H., Jiang, L., Ye, S., Ye, Y., & Ren, F. (2010). Systematic evaluation of antioxidant capacities of the ethanolic extract of different tissues of jujube (Ziziphus jujuba Mill.) from China. *Food and chemical toxicology*, *48*(6), 1461-1465.