



TYPHA PROJECT

ART 3: Typha Management and Economic Use

**Converting Typha (typha spp) threat in
Nigeria irrigation schemes to opportunity
to improve livelihood of farmers**

Deliverable ii

Literature Review on Economic Uses of Typha



POLITÉCNICA



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1. SUMMARY AND INTRODUCTION

Typha (Cattail) is a genus of plants traditionally found in wetland habitats from the Northern Hemisphere. However, during the last decades these aquatic plants are developing rapidly also in tropical wetlands and in the Southern Hemisphere. According to Pandey and Verma (2018) there are at least 30 species of *genus Typha*. These plants are also known as: reedmace or bulrush in British English (NCRS, 2015), cattail in American English (Revedin et al, 2010), punks or corn dog grass, bulsrush or cumbungi in Australia, cattail or bulrush in Canada and kachalla in Nigeria (Ibrahim Lawal Abdullahi, 2011). *Typha* exists in form of different species. Broad-leaved (*Typha latifolia*), narrow leaved (*Typha angustifolia*) and the hybrid (*Typha glauca*) more present in saline habitats (Revedin et al, 2010). *Typha* has edible rhizomes rich in starch grains. There are certain evidences that rhizomes were eaten 30,000 years ago in Europe (Revedin et al, 2010).

Ibrahim Lawal Abdullahi (2011) conducted an in depth study focused on the identification and potential means of control of the *Typha* species present in the Kano Irrigation Project area. The author concluded that *Typha Domingensis* is the species found in the area.

Current world literature on economic uses of *typha* has been reviewed having in mind the two technical objectives of this project: the use of *typha* biomass for production of methane biogas and as silage for animal feed. For completion, alternative uses of *typha* for manufacturing of construction materials and production of charcoal have been reviewed. In addition, we also report current local uses in HVIS based on literature review and own research.

2. USE OF TYPHA FOR BIOGAS

2.1. Digesters: design and features. Use with *Typha* spp.

Anaerobic digester is a physical structure that provides a conducive environment for the growth and proliferation of a group of anaerobic microorganisms that degrades organic matter to generate biogas energy and a liquid effluent rich in nutrients and stabilized organic matter (Abubakar and Bello, 2017).

Local biogas production on farms is related to sustainable agricultural operations. On farm biogas processes of manure and arable waste can decrease methane emissions, reduce odour, pathogens and seed weed germination and raise water quality. (Massé et al, 2011) In industry, bio-digester models have mechanical agitation, temperature control and capacity for hundreds to thousands of m³. However, at the rural or domestic level, the bio-digesters have lower volumes (between 5 - 20 m³) and without regulation or agitation elements, in order to reduce the cost. At the domestic level there are three main types of bio-digesters:

Chinese type: these bio-digesters consist of an underground chamber built with brick or concrete, with two ducts (one entrance and one exit) and an upper opening where the biogas conduction is installed. Its peculiarity is the fixed dome at the top. This immobility causes the pressure of the gas inside to vary depending on its production and consumption. (Figure 1)

Hindu type: these bio-digesters are very similar to the Chinese type, except for the fact that the dome is floating, that is, it goes up or down in function of the internal pressure of biogas. (Figure 1)

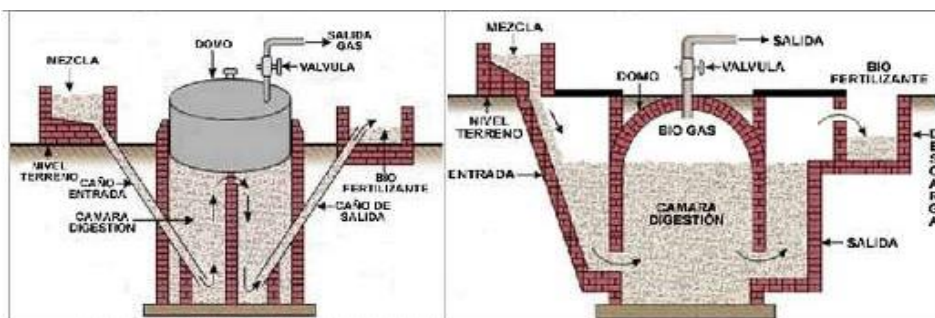


Figure 1. Bio-digesters: Hindu type (left) and Chinese type (right).

Tubular type: these bio-digesters consist of a plastic sleeve to which tubes are installed at the ends that act as inlet and outlet pipes. This type of bio-digester is much cheaper than the previous ones, but with a shorter life, due to the lower durability of its materials. (Figure 2)

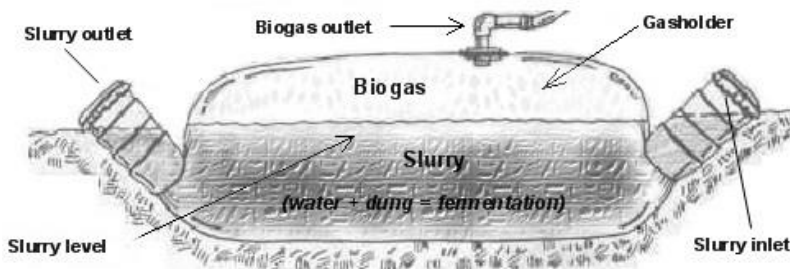


Figure 2 Bio-digesters: Tubular type.

For small producers, the most appropriate technology is bio-digestion in tubular digesters. Due to their constructive characteristics and low cost, they are an adequate alternative to manage the excreta and other organic residues of the farm so that their revaluation integrates them back into the production systems of the farm itself. (Ruiz Ríos and Barberá, 2010)

Energy is required in agriculture for crop production, processing and storage, animal production and electricity for farmstead and farm settlements. It is energy that propels agricultural mechanization, which minimizes the use of human and animal muscles in agriculture. The energy demand required to meet up with the agricultural growth in Nigeria is high and growing every year. (Abubakar and Bello, 2017). In Nigeria, the problem posed

by the use of fossil fuels, firewood, burning of dung cake, improper disposal of animal waste and the nuisance posed by Typha grass makes necessary that farmers to look for alternative renewable sources of clean energy like biogas.

Abubakar and Bello, (2017), developed an anaerobic digester for generation of biogas (Figure 3). In this study the design and fabrication of an anaerobic digester was reported which is an attempt to boost energy requirement for small and medium dry land farmers in Nigeria.

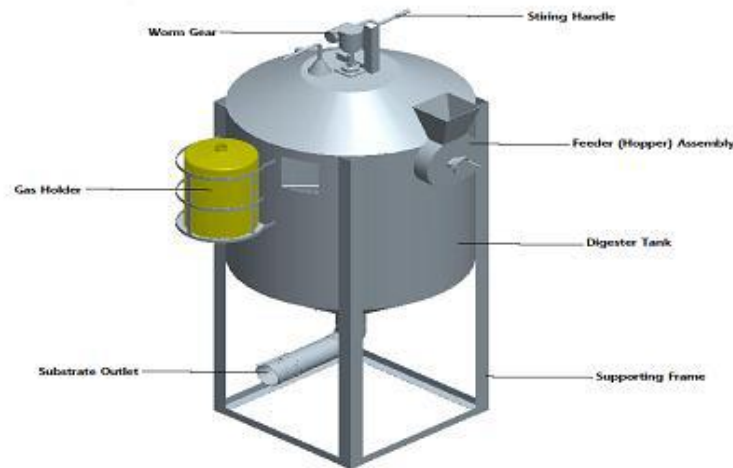


Figure 3 . Exploded view of the digester (Abubakar & Bello, 2017)

The anaerobic digester for biogas production developed was made up of three composite solids of upper frustum, middle cylinder and lower cone shaped bottom with combined volume of 0.974 m³. In designing the digester, the top cover was made frustum shape to accommodate the flat seated worm and worm gear which is centrally located to carry the 22 mm diameter turning shaft. The middle cylinder was made 100 cm in diameter to suit the hopper (feeder) assembly improvised for feeding in the substrates. The lower cone shaped bottom was so shaped to allow for easy flow of spent slurry to be discharged by gravity. The mixing of the substrate inside of the digester is achieved by a worm gear, which is manually powered.

There are other regions in the world with similar conditions to Nigeria, like some areas of Peru, where few of habitants have access to electricity. This lack of supply prevents social, cultural and economic development and creates limitations, especially for school-age people. In this sense, Ruiz Ríos and Barberá, (2010) propose improving the management and treatment of solid and liquid waste, to improve sanitary conditions and at the same time obtain by-products that can be useful as bioenergy resources. These authors show how to build a rural bio-digester for farmers that have connections to the kitchen of the house or animal pens for heating installations.

2.2. Production of biogas from *Typha* spp.

Typha spp. is an aquatic plant with significant amount of lignocellulose (Yue et al , 2007). The anaerobic conversion of cattail could be a great source of biomass to produce clean energy and reduce pollution. In addition, it could also be used for the generation of a variety of fermentation products, which can be recovered as energy resource. However, cellulolytic activity is low and this results in slow growth rates of the anaerobic microorganisms. Addition of cellulolytic microorganisms is sought to improve degradability and efficiency of gas production (Hu et al, 2007)

There is little information about the production of biogas from *Typha* spp without supplementation of additives. Hu and Yu (2006) published that it could be effectively converted into volatile fatty acids (VFA) supplementing with rumen microorganisms in batch cultures. They used an incubation period of 125 h and at different pH. Results were best at a pH of 6.7. The highest volatile solid (VS) conversion efficiency was 66%, total VFA production 371.9 mg/g VS, with a specific growth rate of 0.089 μ /h and soluble total organic carbon (TOC) production of 132.7 mg/g VS. A decrease of pH to 5.8 resulted in a marked reduction in substrate degradability, VFA production and TOC production efficiency. The authors concluded that anaerobic fermentation by rumen microorganisms could be a promising way for effective disposal and utilization of aquatic plants (Hu and Yu, 2006).

Dipu et al, (2011) studied the gas production of different amounts of macrophytes, mixed with cow dung slurry as inoculum. When they mixed cow dung slurry and 25% of *Typha* spp slurry the maximum gas production was 50 ml at 4th day of fermentation. With 50% of *Typha* spp the maximum gas production was also 50 ml, but it was produced in 7th day. With 75% of *Typha* spp slurry the maximum gas production decreased to 45ml in the 7th day of the fermentation. When only *Typha* was introduced in the bio-digester, the maximum gas production was 65 ml on the 7th day. The overall production of biogas using *Typha* alone was 205 ml, more than that the 60 ml obtained with the cow dung slurry. However, this production was slow. The authors concluded that adding cow dung slurry the process could be accelerated.

Jiang et al (2014) explored the potential production of biogas of wetland aquatic biomass plants with an inoculum from a biogas digester in a pig farm. The results show that the anaerobic biogas potential production (ABP, mL/ g VS) of aquatic biomass plants is different for different components content. These authors found a significant and negative correlation between anaerobic biogas potential production (ABP) and hemicellulose content, and the correlation between ABP and starch carbohydrate content was significant and positive. The daily biogas production rate of fermentation for *Typha orientalis Presl* was the highest at the first day of fermentation with the peak values of about 800 ml/day. The curves of biogas production of *Typha* show that the production rate drops rapidly. The first valley occurred in 3-4 days. The authors explained that this was because the fresh inoculum provided sufficient bacteria for acid production and development of methanogenic bacteria for methane production in the very beginning. On the other hand, Jiang et al. (2014) observed that the easily degradable carbohydrate content of the fiber aquatic biomass plants was low, the fatty acids content produced through hydrolysis was low. The activity of methanogenic bacteria decreased

and their growing metabolism was slowed down. Thus the biogas production rate gradually decreased. With the decomposition and utilization of carbohydrates, proteins, lipids and other substances in the raw materials, the activity of bacteria for methane production is gradually recovered. Thus, the production rate for *Typha orientalis* reached a second peak of biogas production in 5- 6 days. It will be of importance to characterize well the type of gas which is produced during the first stage of fermentation and in the second fermentation.

Martens et al. (2017) used 20 bio-digesters during 21 days to investigate the impact of plant species *Phragmites australis* (Pa) and *Typha latifolia* (Ti) and nutrient status on GHG emissions, biogas production and methane yield. These authors found a mean production of 177ml CH₄/ g VS (Pa) and 204 ml CH₄/ g VS (Ti). They also observed the yields after adding N in the samples. Samples collected from the greater N supplementation resulted in a greater methane yield, which raised from 177 to 230 ml CH₄/ g VS. However, plants supplemented with a high N load (500 kg/Ha) had a much lower C / N ratio than those with the low N load (75 kg/Ha)

Several other authors studied the *Typha* spp methane yield, and found very variable volumes of production. Alvinge et al. (2010) reported about 300 ml CH₄/g VS, Nkemka et al (2015) reported 151 ± 21.4 mL CH₄/ g VS, Martens et al. (2017) obtained 145-226 ml CH₄/ g VS for *Typha angustifolia* and 152-252 ml CH₄/ g VS for *Typha latifolia*. Also, Diouf et al. (2016), in Senegal, using *Typha Domingensis*, after 37 days of fermentation in a 1000 ml digester with 150 g biomass, obtained a cumulative production of biogas of 8955 ml titrating 40.4% methane, is 59.70 ml / g of biomass.

Adelere and Uduoghene (2017), investigated the potential of biogas production from three wetland macrophytes: Water hyacinth (WH), cattail (CT) and *Cyperus papyrus* (CP). Observations were made for a period of 128 days (Figure 4). The results show that the three macrophytes produced methane (CH₄) and carbon dioxide (CO₂) in reasonable quantities, been water hyacinth the best, cattail the second y *Cyperus papyrus* the lowest. The mean percentage CH₄ production for *Typha* sp. was 42.02±11.10 %. The energy potentials in terms of calorific value were 7.02 W/kg of biomass.

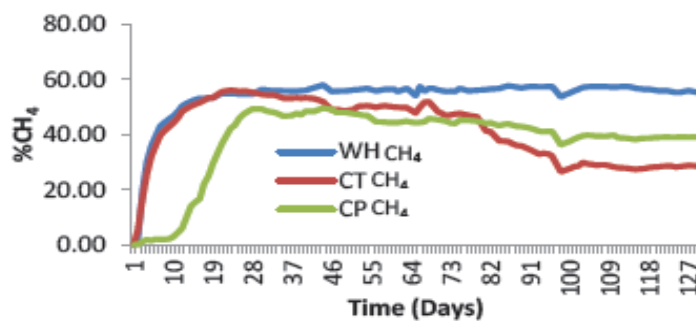


Figure 4. Observed %CH₄ production rate of WH, CT and CP.(Adelere and Uduoghene, 2017)

Most authors agree that Typha is a relatively high lignocellulosic plant which decreases yields in methane production, therefore, they seek to improve the production of methane with some previous treatment or adding, to the fermentative inoculum, something to increase production.

A summary of results obtained in different research studies is shown in Table 1, the use of cattail to produce biogas could be considered in terms of renewable energy sources and can be carried out at a decentralized local level.

Table 1. Production of methane (CH₄) obtained in different research studies

References	Units	CH ₄ production
(Dipu, Kuma, & Salom Gnana Thanga, 2011)	% CH ₄ in the total gas produced	205
(Jiang, Song, Chen, & Zhang, 2014)	ml/g VS	513.2
(Alvinge, Karlsson, & Sundblad Tonderski, 2010)	ml/g VS in 11 days ml/g VS in 37 days	220 300
(Nkemka et al., 2015)	ml/g VS Unaugmented ml/g VS Bioaugmented with <i>Piromycesrhizinflata</i> YM600	151 146.5
(Diouf, Sow, Diop, Sambou, & Diop Sall, 2016)	ml /g MS	149.2
(Adelere & Uduoghene, 2017)	% of the total gas produced	42.02
(Martens, Karlsson, & Mattsson, 2017)	ml /g VS (<i>Typha angustifolia</i>) ml /g VS (<i>Typha latifolia</i>)	177 204
(Mshandete, 2009)	ml /g VS of leaves, stems, roots, rhizomes and whole cattail	>280

The biogas can be used directly for heating, cooking on site thus reduces energy imports. The surplus energy can be easily converted into electricity or be exported as piped or compressed.

2.3. Treatments of Typha to improve its degradability.

Typha is relatively high in lignin. Lignin is a complex organic component of the plant cell wall which gives strong resistance to the plant. However, lignin is not easily degradable by biogas producing microorganisms. This complex structure of lignin may be physically broken down using pre-treatments like steam, chopping or grinding the to facilitate accessibility of the microbes to the intra-cellular contents.

Alvinge et al. (2010), using *Typha latifolia*, observed that the final methane yield was 300 mL CH₄/g VS and it increased by 16 % on the average when a milling pre-treatment was used. Moreover, when an alkaline pretreatment with lime increased was used, the yield increased by 27 % at room temperature and by 22 % at 55 °C. On the other hand, a fungal pre-treatment decreased biogas production by 20 % and thus, the authors conclude that probably this fungal treatment is not suitable for this kind of substrate.

Also, Taherzadeh and Karimi, (2008) found that milling and alkaline pretreatment increased the biogas yield by about 15 and 25 %, respectively. However, these authors pointed out that pretreatments in practice must always be cost-effective having in mind the costs of energy, chemicals and water when applied in a large scale.

Nkemka et al., (2015) suggested that bioaugmentation with *Piromyces rhizinflata* YM60 produced several benefits like: improved the speed of initial H₂ and CH₄ production rates, and improved degradation rate of volatile fatty acids (VFA), which is beneficial for anaerobic digestion processes avoiding accumulation of VFA, which would otherwise inhibit fermentation. These authors concluded that bioaugmentation with anaerobic fungi has the potential to improve the performance of anaerobic digestion systems.

Yildirim et al. (2017) also investigated alternative treatments using bio-stimulators to facilitate the start of fermentation and improve the production of methane in bio-digesters. These researchers inoculated a mixture of rumen fungi containing 4 species in equal ratios of anaerobic rumen fungi: *Orpinomyces* sp., *Piromyces* sp. and *Anaeromyces* sp., *Neocallimastix frontalis*. These species were selected and added to manure and thoroughly mixed to obtain a homogeneous inoculum. The inoculum was added in the anaerobic digesters at different ratios: 0% (R0), 5% (R1), 15% (R2), 20% (R3) (v/v). From these results, it was concluded that high concentrations of anaerobic rumen fungi improved methane yield (Figure 5). The highest efficacy was observed in the digester with 15% inoculum (R2) which reached almost 60% of methane of the total biogas produced. The lowest methane production was observed in digester which had no manure added. As shown in Figure. 5, a significant increase ($p < 0.05$) in methane production was demonstrated between the start-up stage and the steady stage. At the end of the 40-day period, the steady stage was reached, and methane production was stable in all anaerobic digesters

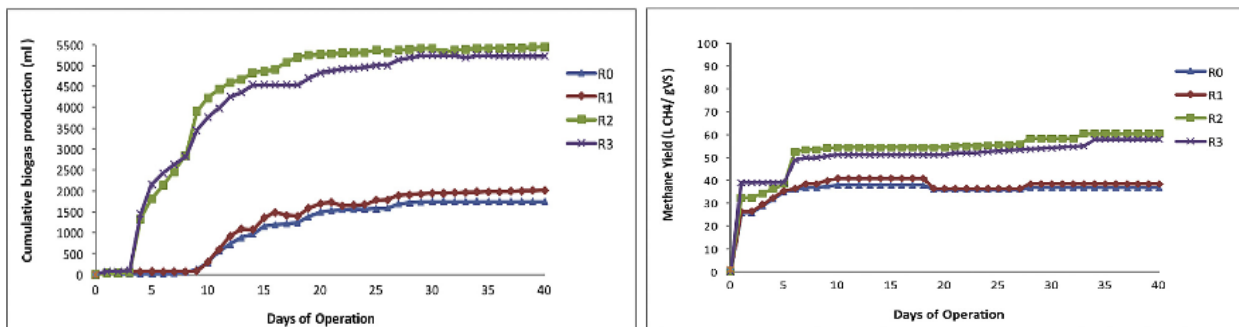


Figure 5 . Biogas production and methano yield in the R0, R1, R2 and R3 reactors. (Yildirim et al. 2017)

Yildirim et al (2017) concluded that a concentration of 15% anaerobic rumen fungi proved to be the most efficient to improve bio-methane production in anaerobic digesters fed with animal manure. However, this research was done without addition of biomass from Typha.

Having in mind the research studies mentioned above, it would be of interest to conduct new trials using biomass from Typha inoculated following the methodology used by Yildirim et al. (2017) and evaluate methane production.

2.4. Conclusion

Typha is a lignocellulosic plant hardly degradable. The efficacy of methane production from Typha is around 40% of the total gas production, as shown in recently published literature, however variability is very large and factors of variation are not well described. In order to increase this efficacy it will be required to accelerate the rate of digestion of the complex structure of lignin. The use of previous treatments such as, partial drying, shredding, chopping, milling, steaming and enriching with microorganisms with high hydrolytic capacities should be investigated.

Typha biomass has potential as feedstock for production of bio-methane, however, further research is needed to define optimal harvesting, processing and fermenting condition and to have a good evaluation of the efficiency of conversion of Typha biomass into useful biogas.

A sustainable use of Typha will not compete with scarce food resources. Production renewable biogas from Typha will increase accessibility of rural households to clean energy and reduce dependency on fossil fuels. Moreover, the residue from biogas production is known to be of good as fertilizer on farmland.

3. USE OF TYPHA FOR ANIMAL FEED

3.1. Introduction

Roughages are the main feed for livestock in northern Nigeria. The shortage of feed in terms of quality and quantity especially during dry season is one of the most serious problems faced by farmers in this region. To overcome feed shortage during dry season, by-products from agriculture and other industries are usually fed to cattle in the form of roughages or concentrates. Use of preserved surplus of various kinds of raw materials such as fresh grasses and residues in the form of silage are fed to cattle in dry season (Alao et al., 2017).

An updated review of the literature about the nutrient composition and uses of typha for animal feed is shown below.

3.2. Chemical composition

To assess an animal feedstuff it is important to know its chemical and nutrient composition. A summary of the results obtained from the published literature are shown in Table 2.

Table 2. Chemical composition of *Typha* spp. from different authors

Published literature	DM	Ash	CP	NDF	Hemicellulose	ADF	ADL	Cellulose	FAT
Wing Ching et al 2018. 4 months	14.56	11.4	7.83	61.76	24.72	37.04	3.98	33.06	3.39
Wing Ching et al 2018. 12 months	20.72	8.25	5.97	70	26.16	43.84	6.32	37.52	2.77
González et al. (2000)		18.2	13.3	56.1	22.8	33.3	3.51	29.79	
Kinupp and Barros (2008) (SHOOT)			16.1						
Do Nascimento et al. (2014) LEAF	19.1	8.2	11.5	75.9	25.7	50.2	14.1	36.1	1.9
Do Nascimento et al. (2014) SHOOT	15.1	7.1	3.2	80.1	27.3	52.8	8.9	43.9	0.2
Average	17.37	10.63	8.77	68.43	24.43	44	8.00	36.07	2.23

Important variability can be observed in results shown in Table 2. Part of this variability is most probably due to the different species of *Typha* used in each study, different part of the plant analyzed, and different stage of growth.

One important part of the *Typha* are the tuberculous roots, known as rhizomes, which may have more than 70% starch on dry matter and are also rich in protein (Fahlgren, 2017). Rhizomes also could be a good source of energy for animal feed. More studies are necessary with this plant to have a better characterization

of its chemical composition and nutritive value. No references have been found on animal nutrition studies using *Typha* grass or rhizomes from the West African Region.

3.3. Nutritive evaluation- Relative Forage Value

In Tables 4 and 5 an estimate of the quality of *Typha* as fodder is shown. According to equations proposed by FEDNA (Calsamiglia, Ferret, & Bach, 2016) the relative value of a forage (RVF) can be classified as: Excellent (RVF > 151), first (RVF 125-151), second (RVF 103-124), third (RVF 87 -102), fourth (RVF 75-86) and fifth (RVF < 75). This index is an objective assessment of forage quality that reflects the dry matter ingestion potential ($DMI = 120 / \% NDF$) and its digestibility ($DMD = 88.9 - (0.779 * \% ADF)$), where $RVF = (DMI * DMD / 1.29)$. The highest RVF was obtained by Gonzalez et al. (2000), with samples collected from young *Typha*, which was cultivated in an experimental station..

Table 3. Relative value of the forage (RVF) calculating with the equations proposed by FEDNA based on analytical values extracted from the literature.

Published literature	NDF	ADF	DMI	DMD	RVF
WingChing. 4 months	61.76	37.04	1.94	60.05	90.44
WingChing. 12 months	70	43.84	1.71	54.75	72.76
Gonzalez et al. 2000	56.1	33.3	2.14	62.96	104.4
Kinupp et al. 2008 (SHOOT)					
Do Nascimento et al. (2014) LEAF	75.9	50.2	1.58	49.79	61.03
Do Nascimento et al. (2014) SHOOT	80.1	52.8	1.5	47.77	55.48
Average	68.62	44.00	1.78	54.63	76.21

3.4. Feed uses

Typha grass could be used to make quality silage to feed ruminant animals during dry season. As mentioned earlier and also recognized by the local communities of the Hadejia region, young *Typha* grass is consumed by ruminants when small, but it is not as desirable as corn (Alao et al., 2017). For this reason, preserving it as silage will make it more palatable and nutritious which could help to improve the economic situation of farmers. The scarce information published on the inclusion of *Typha spp* for ruminant feeding is summarized below.

In Costa Rica, some studies with hay and silage of *Typha Domingensis* have been published (WingChing-Jones and Leal Rivera, 2018). Both hay and silage enhance the nutritive value and improve its conservation for the critical periods of low availability of forage. In the case of silage, it could be necessary to add molasses, which would favor the conservation of the dry matter and the content of soluble carbohydrates for fermentation. Also, it could be necessary the inclusion of urea when the protein does not reach the minimum of 7% required in forages to maintain good consumption and the activity of the rumen microorganisms.

Also addition of enzymes can improve on the digestibility of *Typha*. Dehghani et al. (2012), suggested that adding fibrolytic enzymes to forage at ensiling can solubilize some of the easily digestible parts of cell wall carbohydrates and thereby supply substrates for lactate fermentation.

Queiroz and Silva (2014) have verified the effect of the addition of *Typha spp.* on sugarcane silage. The inclusion of the cattail in the silage of sugarcane provided a positive associative effect by substantially improving the fermentative characteristics and the nutritional value of the silage.

Do Nascimento et al. (2014) evaluated the chemical composition and in vitro digestibility of fiber from different parts of *Typha* plants. This plant, supplied entirely to animals, has a nutritional value in which its protein content stands out with average values of 8% and the availability of fiber higher than 80%, constituting a forage option for ruminant nutrition.

Cattail present a nutritional potential for the formulation of diets for ruminant animals since they contain part of the minimum requirements of the 6.25% CP and considerable mineral content for the action of microorganisms in the digestion of fiber (Pinedo and Santos, 2008). However, it is necessary to evaluate the anti-nutritional effects and the voluntary consumption of cattail by ruminants. Its consumption was already proven in mixtures of *Typha spp.* with plants of elephant grass (*Pennisetum purpureum Schum*) or sugar cane (*Saccharum spp.*) in a period of scarcity of fodder in the State of Espírito Santo, Brazil, but, for now, these data were not cataloged in the scientific community.

Furthermore, it has been described that *Typha domingensis*, ground and added in water, administered orally to goats presents a potential for alternative programs of control of gastrointestinal nematodes in goats, but subsequent studies being necessary (da Silva et al., 2011) The problem of feed supply to small ruminant seems to be enormous and so the need for investigation and search for alternative, less expensive and locally available sources of protein for ruminants become more important.

It would be of great economical interest to develop the practical use of *Typha* for feed in similar manner to what Olubukola et al. (2013) did with *Ficus mucosa*, *Ficus capensis*, and *Spondiamombin* which are common domestic trees in many parts of Nigeria. They determined the proximate, fiber, and mineral compositions of leaves, soft twig, leaves plus soft twig, and bark of these plants as potential fodders for ruminant production. This study showed that *F. capensis* and *S. mombin* leaves are good sources of protein, ash and fiber while *F. mucosa* is rich in mineral elements such as sodium and potassium and needed to be supplemented for

other macro and micro elements for effective use as alternative feed resources to meet the nutrient requirements of small ruminant animals

3.5. Conclusions

A lot of information can be found about the use of Typha for food worldwide, but very little scientific information is available on the use of Typha for animal feed. As reported Wing Ching-Jones and Leal-Rivera (2018), from the Zootechnic University of Costa Rica, have reported that Typha hay is an acceptable alternative source of forage near the wetlands. The same authors found that Typha properly ensiled with addition of urea and molasses has an adequate nutritional value since it could be used to replace nearly 50% of the daily diet when no other feeds are available. Drying to make Typha hay and ensiled Typha can be interesting ways to preserve Typha roughage for the critical periods when feed is not available or difficult to buy.

The estimated Relative Forage Value (RFV) of Typha, calculated from analytical results of plant composition from the literature is 76.2. However, results the RFV can vary a lot depending on the plant fractions and the physiological state. Studies are needed with harmonized analytical procedures to reduce the variability between laboratories and within vitro determination of digestibility to have a better evaluation of the nutritive value of Typha for ruminants.

Research is needed to determine the degree of acceptability by the animal have a better evaluation of the nutritive value according to a, physiological stage of the plant. Also a more exhaustive characterization of undesirable and potentially toxic substances should be done to decide upon the recommended dose of utilization in practical feeding.

Other species of plants can be introduced into wetlands, such as *Aspargamium*, with the same invasive capacity as Typha, to compete with it, but with a better chemical composition for use as fodder in ruminants of better quality.

4. OTHER ALTERNATIVE USES

4.1. Local uses

. There are few studies of local uses of Typha, however, the most frequent local uses of Tyla are for construction and handicrafts. Abdullahi (2011) reports that Typha stalks are commercialized at the “KwanarGafan” tomatoes market such as articles to tomatoes traders who use it to preserve and transport large quantities of the crop across the country during the tomatoes season. This activity represents an important source of income for some people and this activity seems to be expanding to nearby states like Jama’are in Bauchi State. Cutting and selling Typha stalks contributes substantially to the management of

the weed in the area at present and perhaps in the nearest future, because it is readily available, cheap and convenient to use. According to the result of focus groups in and the surveys developed by members of FUGA, local farmers report that goats eat young Typha

A review of the different Typha uses worldwide is found in Pandey et al. (2018) who reports Typha is used in the artisanal market and the industry. Typha plant also has culinary uses and the seeds have linoleic acid content Pandey et al. (2018). Another important fact is that the fiber of Typha might be used to prepare crude material, and also Typha might make utilized concerning illustration as wellspring for starch to prepare ethanol. This author reports that the Typha plant has many uses such as manufacturing furniture, culinary uses, building material and biofuel.

4.2. Typha use as insulation material[†]

Nowadays, sub-Saharan buildings are built with cement block and zinc sheet. They are considered the best materials under social standards and boost by governments, at different scales. It gives priority to the use of those conventional building materials and technologies in building codes and regulations. In addition, they prevent the use of local building materials and technologies and the use of cost-effective and environmentally-friendly construction technologies.

As consequence, buildings are not adapted to the local climate with high rates of insolation and are making life impossible indoors. Furthermore, 53% of Nigerians consider climate change a very serious problem (World Bank Data). Therefore, climate change mitigation is now part of several regional strategies in Nigeria. In relation to this, the government is promoting biofuel industry based on local resource like cassava or sugar cane (Un-Habitat, 2011). Although they do not target yet the improvement of energy efficiency through new building techniques, thermal insulation strategies in building sector would reduce the effects of climate change indoors. It improves thermal indoor comfort without energy requirements. It becomes to be of great interest since between 25% and 30% of the total electricity supply in West Africa is consumed in the building sector (UNDP Senegal, 2016). What is more, in Nigeria, only 18% of the connections works along the whole day (Abel Oyuke, Penar, & Howard, 2016) in spite of 96% of the population had connection to the electricity. Indeed, the inefficiency of the system provokes that 32% of Nigeria population consider the electricity the most important problem that government should address (Abel Oyuke et al., 2016).

On the other hand, together with the inefficient quality of the housing sector, another problem is the high cost building materials. They achieve up to 80 % of the total value of a simple domestic house (Un-Habitat, 2011). This circumstance and the fact that 53% of Nigerians are out of financial services (Un-Habitat, 2011), provoke that their unique solution would be the informal sector. Furthermore, in most Africa, local building materials industries are not homogeneous and that has many shortcomings. It has poor productivity, which leads to shortages and price fluctuation, and it has not a facility to diversify into new product lines (Un-Habitat, 2011).

[†]External collaboration by Adela Salas Ruiz, Group ICHAB-ETSAM.UPM

At small-scale sector, it is due to their poor technological capacity besides low incomes which justified the search for sustainable solutions adapted to the economic, social and environmental context.

4.2.1. Insulation building material

In the case of Nigeria, and specifically the Hadeija Valley, the use of Typha (or cattail) as a thermal insulation material can be a qualitative improvement of existing buildings. In fact, cattail is already used as a traditional roofing material by Fulani local communities

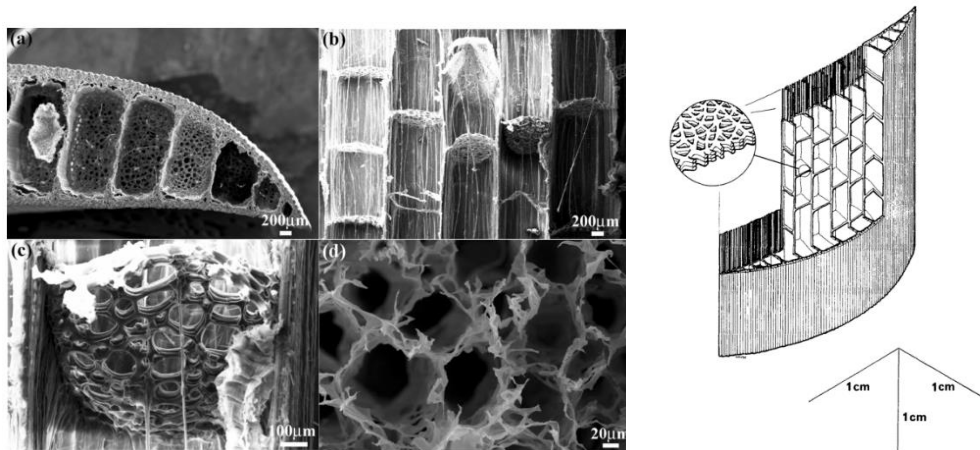


Figure 6. Left: Microstructure observation of the Typha leaf: (a) cross sectional microstructure; (b) longitudinal sectional microstructures; (c) diaphragm; (d) foam tissues. Source: (J. Liu et al., 2018). Right: Isometric section view of thypha leaves. Source: (Rowlatt & Morshead, 1992)

Typha is a very porous and low-density plant due to it is a macrophyte nature. Its inner morphology is plenty of air voids () which is a great advantage since its thermal behaviour would be better than in other plant fibers (J. Liu et al., 2018; Rowlatt & Morshead, 1992). Although, the mineral concentration depending on water and nutrient supply, the plant age or developmental stage, Typha has high cellulose content (67.3%) which is a good value to use it in a reinforced alkaline or polymer matrix (Razig, Jaouadi, Khoffi, Msahli, & Durand, 2016). On the contrary, Typha is rich in lignin (13.65%) (Razig et al., 2016) compared with another types of fiber such as hemp, flax, ramie, kenaf, banana, curaua, cotton or nettle (Gurunathan, Mohanty, & Nayak, 2015). In all of them, several experiments were carried out to study the suitable conditions for extracting fibers (Scholar et al., 2016) even from Typha leaves (César, Pereira-da-Silva, Botaro, & de Menezes, 2015; Razig et al., 2016; Timilsena, Abeywickrama, Rakshit, & Brosse, 2013; Witztum & Wayne, 2016). The cross-sectional geometry and inner structure of the Typha leaves exhibit high strength, low density and gradient distribution from base to apex (J. Liu et al., 2018; Zhao et al., 2015) According to the literature, the most suitable pre-treatment would be based on the use of NaOH (Razig et al., 2016).

Typha as a construction material is investigating by other African countries with the same Typha invasions problem such as Senegal. Since, thermal insulation is no common practice in the Senegalese building

tradition, as other countries in sub-Saharan Africa, there are an absence of thermal insulation material in local commerce (beyond synthetic products imported from Europe). It implied that their prices would be prohibitive and unaffordable while no widespread. From this point of view, insulation materials based on Typha are a potential business for local producers while it is a tool to control the plague. The UNDP (United Nations Development Program), together with local stakeholders, has carried out a project focused on Technology transfer in order to use Typha as an insulation material with different applications (Figure 77) (UNDP Senegal, 2016).

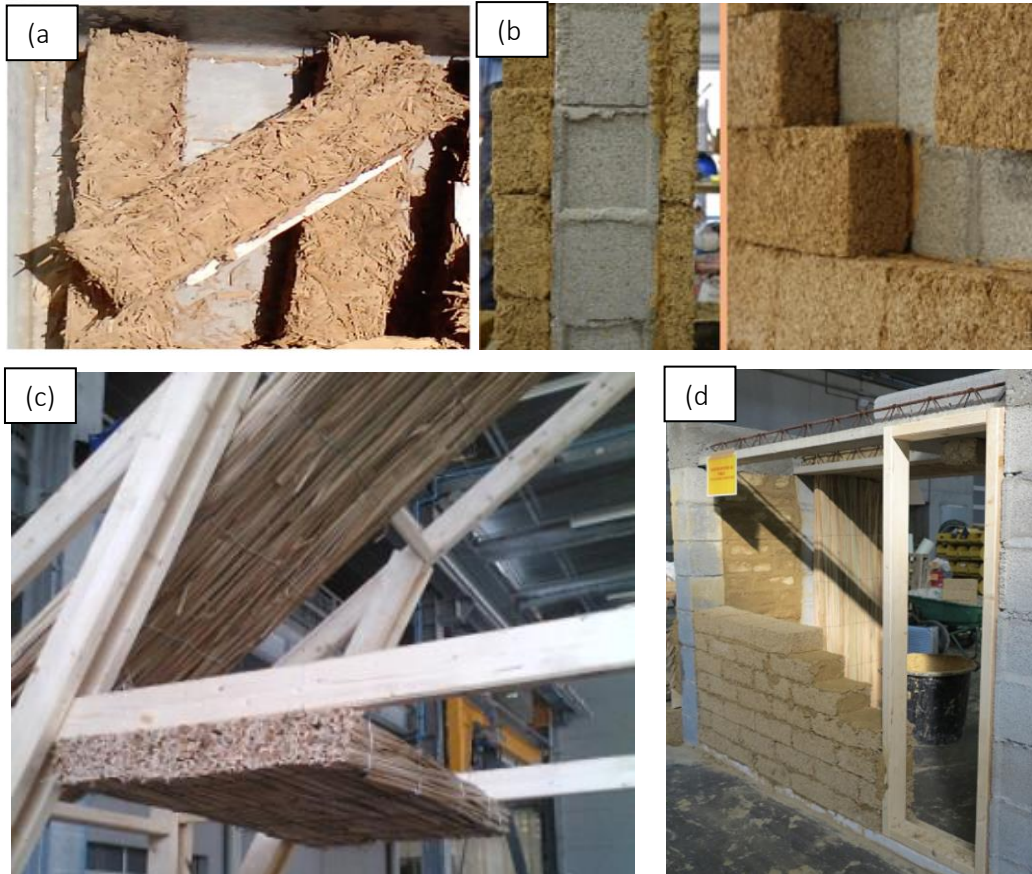


Figure 7. (a) Picture of clay-samples for the mechanical test; (b) clay-fiber blocks for improvement existing walls; (c) Typha-roof proposal and (d) Clay-Typha walls proposal (UNDP Senegal, 2016).

In terms of research-development, the use of the Typha was studied with different blending materials such as clay, cement or plaster. They were used for new buildings and for the improvement of the existing ones. In addition, a proposal of double-sheet plant roof based on Typha was studied.

In the case of clay as a binder, it was founded that Typha-clay blocks were an interesting alternative for imported and expensive insulation materials (Dieye et al., 2017). Their compression and tensile strengths respectively varies from 0.279 to 0.796 MPa and from 0.340 to 0.969 MPa at weight percentage of binder

range from 77% to 85%. The thermal conductivity of dry materials varies from 0.117 to 0.153 W/Mk (Dieye et al., 2017) which is a good value for an insulation wall.

On the other side, economic and social assessment was developed in order to identify the implementation barriers. It proved that it is necessary design a modular, decentralized process that can be accessible for national investors and define the minimum production scale that will allow commercializing products at competitive prices. Appropriation and replication of the project by national investors is a key factor of success of the project. Local technical capacities are scarce, so manufacturing process must be ease and scalable (UNDP Senegal, 2016).



Figure 8. Cattail Fiber (left) and panel (right) (Asdrubali, D 'alessandro, & Schiavoni, 2015)

On the other hand, in developed countries research groups are studied the thermal properties of Typha from a long time ago. The first patent for producing an insulation material made of cattail fibers was already published in the USA in 1962 (Vincent, 1962). Nowadays, bio-composite (insulation materials made by resin matrix and a reinforcement of natural fibers) is the main studied application (Bajwa, Sitz, Bajwa, & Barnick, 2015; Ibrahim et al., 2013; Luamkanchanaphan, Chotikaprakhan, & Jarusombati, 2012; Moghaddam, Safi, Hassanzadeh, & Mortazavi, 2016; Ramanaiah, Ratna Prasad, & Hema Chandra Reddy, 2011; Sana et al., 2015). The usual blending materials are polyester, Methylene Diphenyl Diisocyanate (MDI), Unsaturated polyester resin (PES), polypropylene or Polylactide acid (PLA). In fact, PLA is one of the most promising biodegradable polymers owing to its mechanical property profile, thermoplastic processability and biological properties, such as biocompatibility and biodegradability (Ibrahim et al., 2013). It was founded that Typha-board had a good thermal and acoustic behaviour, similar to other insulation material coming from natural fiber (Schiavoni, D 'alessandro, Bianchi, & Asdrubali, 2016). In particular, Typha- MDI board with a density of 200-400 kg/m³ had the thermal conductivity values ranging from 0.0438-0.0606 W/m.K (Luamkanchanaphan et al., 2012). According to the investigation it is found that the research and application of bio-insulation are still far from a wide scale commercialization (L. Liu et al., 2017)..

Another kind of investigated solutions are Typha-reinforced board with binder such as magnesite (Krus, Theuerkorn, Großkinsky, & Künzel, 2014), plaster (García Santos, 2003) or cement (Oumar Abdelhakh et al., 2016). These materials show good thermal and acoustic behaviour. However, their higher density compared to bio-composites made them less efficient in developed context. Regarding this, it must be highlight the binder-free cattail fibreboards which are free of any type of glue. They showed good mechanical performance compared with other types of natural fibers board. It was unfeasible with other natural fibers such as hemp, flax, kenaf in which a suitable bonding resin is required. The binder-free Typha mats were compression moulded to panels at a constant press temperature of 160°C and at a constant pressure of 80bar (Wuzella, Mahendran, Bätge, Jury, & Kandelbauer, 2011).

Currently, in Germany and Austria, a market for Typha insulation has already successfully established. One of the major companies on the insulation market is “Naporo”, an Austrian brand founded in 2009 with around 8 patents (Colbers, Cornelis, Geraets, & Gutiérrez-Valdés, 2017). Meanwhile, the Fraunhofer Institute for Building Physics (Germany) has developed Typha based insulation panels, characterized by a thermal conductivity of 0.052W/Mk (Colbers et al., 2017; Fraunhofer-Gesellschaft Institute, 2013). Unlike Senegalese’s investigation, particle board is the most popular insulation material used, because of its advantage in a wide range of input material and its manufacturing processes and cheap production price in developed countries (Colbers et al., 2017). However, and as above mentioned, in African contexts the production of panels is more expensive due to the high cost of raw materials and energy requirements.



Figure 9. Left: Blow-in insulation material from 100% cattail in a display case, and construction panels made of cattail. Source: (Colbers et al., 2017). Right: Fibermat typha (Wuzella et al., 2011)

As summary, Typha is a potential raw material for thermal insulation constructions in Nigeria. Its use could trigger the creation of small local business for its production, while improving building and life quality of local communities too. Several investigations from Europe and East Asia confirm its relevance. However, in order to transfer the technology to Nigeria, technical solutions need to be adapted. The challenge, launched at UNDP-Senegal, is to develop custom constructive technologies based on Typha for local commerce; both for its producers and for its final users. It must take into account the lack of technical capacities as well as stable energy source. It should be highlighted the great capacity for small-scale growth and also its cheap labour force and low-cost raw materials.

The potential for converting the threat posed by Typha invasion into a sustainable and promising alternative for local communities in rural areas under schemes such as green communities and regions is a. Typha would be established as a building material in the construction of new buildings and retrofit. Moreover, it would create many new jobs for local communities based on a sustainable building material. However, further research based on Typha should be developed in order to adapt it to Nigerian framework, its society, its market and its environment.

4.3. Typha based bioenergy projects in West Africa[‡]

3.3.1 Introduction

In 25 countries, mostly in sub-Saharan Africa, more than 90% of households rely on wood, charcoal, and waste for cooking. Specifically, 94% of population in Nigeria does not have access to clean energy. This situation is particularly acute and poses an enormous threat to poor and vulnerable populations in West Africa. In this section we present a review of the projects and companies of Typha valorization as domestic fuels in Senegal.

3.3.2 Projects and companies of Typha valorization as domestic fuels in Senegal

CNT :Coumba Nor Thiam

Representative:Mr Papa Makhtar NIANG

- Coumba Nor THIAM, created in 1987 under the status of an GIE, became a SUARL in 2007. It is based in the village of Thiagar located in the region of Saint-Louis, (Department of Dagana, commune of Ronkh).
- Since 2010, the company Coumba Nor Thiam has a unit for producing electrical energy from rice husks. This unit (an Indian technology) remains a major innovation because it deals with the waste resulting from the transformation of rice (rice husk combined with water and oxygen) into electrical energy. This technique avoids any pollution of the environment by rice husk.
- It is in this same dynamic that a partnership is initiated between CNT SUARL and GIZ PERACOD (Programme for the promotion of renewable energy, energy efficiency and access to energy services, Commissioned by German Federal Ministry for Economic Cooperation and Development) to launch the production and sale of pellets and Typha briquettes as cooking fuel. This activity strengthens the social responsibility of the company and at the same time offer alternatives in an area where firewood is scarce and expensive.
- Two types of fuels are produced: pellet and briquette.
 - ❖ The pellet is made by a pellet press called backhoe. It is used primarily to grind and granulate the milled Typha with an optimal daily production capacity of 80 kg or 11 kg per hour.
 - ❖ the briquette is manufactured by a Briquetting press type Genius. The material is fed into the container either manually or by a filter or conveyor. The machine can produce 25 to 30 kg of fuel per hour.

BRADES

Representative: Nthié DIARRA, tél : 221 77 641 21 49, Email: bradesenegal@yahoo .fr

[‡]External collaboration by Candela De la Sota Sandez, UPM

This small family business was established in 2007. It makes charcoal from charcoal residues collected in the stockyard, mixed with clay and water. The mixture is then agglomerated in the form of briquettes by a press (manual press at the beginning, now relayed by a mechanized press). The product is then dried and packaged in paper bags made by the company from bags of cement. BRADES, which is assisted by PERACOD, has made significant efforts in the field of promoting biochar to the population. Its production has reached 12 tons of biochar per month since 2012. Its product is marketed at a price of 150 FCFA / kg.

Pro-Natura International (Ross-Béthio, parc de la SAED)

Local manager:M. Ndiaye

This Franco-Brazilian NGO has developed in Ross-Béthio a Pyro-6f machine, which has been running since 2007. The Pyro-6f is an innovative pyrolyzer that produces green charcoal from renewable biomass: rice husk, Typha or any other agricultural residue sufficiently dry. The biomass is crushed and injected into the Pyro-6f which carries out a continuous carbonization at 500 ° C without emitting greenhouse gases. Then, the pyrolysis gases are recycled to maintain the high temperature in the combustion chamber, which makes the process autonomous as soon as preheating is complete. Finally, after cooling the green charcoal powder, it is mixed with a natural binder (clay, millet flour ...) and then compacted in the form of briquettes or pellets ready to be used in traditional cooking stoves just after drying. The expected production from a mix Typha / rice ball or Typha alone could reach ten tons of green charcoal per year

PERACOD (Richard Toll)

The PERACOD (Program for the Promotion of Rural Electrification and Sustainable Domestic Fuel Supply), developed with the help of the German Technical Cooperation (GTZ), has created an "Alternative Domestic Fuels" (ADC) branch. In parallel with its partnership with BRADES, PERACOD in 2006 developed a biochar production unit from Typha, an invasive plant that grows in the waters of the Senegal River. This unit uses simple technology that can be replicated on a large scale in rural areas. It has a production capacity of 120kg per day per unit of production. The product, manufactured in the suburbs of Richard Toll, is transported to the city and provided to the women of a federation with about twenty GIE. Each group president buys a quantity of the product that she will distribute per pot to the women members of the GIE for the purchase.

GRET

The NGO Gret has implemented, in partnership with local actors, projects for the production of domestic coal from Typha australis in villages along the Senegal River.

- The **TyphaMauritanie project**, conducted between September 2011 and April 2016, enabled the development of the "Typha charcoal" product from a production process adapted to Mauritanian villages. Seven artisanal Typha charcoal production units were installed in villages and a semi-industrial charcoal production line was tested;

- Following this successful first phase, a new phase was initiated in Senegal through **the Typha Senegal project**, which started on May 1, 2016. This project aims to set up a local sustainable and inclusive Typha charcoal industry, which is the creator of income-generating activities, through technology transfer Mauritania-Senegal. Six new artisanal units have been planned to be set up by April 2018. Three companies in the villages of Ronkh, Pomo and Mbagam have been set up as part of this project to produce organic charcoal.

5. CONCLUSION

Typha is an invasive plant colonizing irrigation channels, rivers and agricultural lands. It interferes with fishing, reduces agricultural production, and promotes the persistence of waterborne diseases such as bilharzia and malaria. This invasive growth is a major problem in the Hadejia Valley in Northern Nigeria, where the economic activities, health and wellbeing of local communities are threatened.

In this report, we presented a comprehensive literature review on the use of Typha for Biogas and animal feed. There is a large amount of literature available about production of biogas, from multiple organic residues, but only few published papers refer to biogas from Typha grass. Some of these works provide evidence that the anaerobic conversion of cattail can be a great source of biomass to produce clean energy and reduce pollution. Methane production efficiency has been estimated to be around 40% of the total gas production, with values ranging between 60 and 300 ml/g of volatile solids. One challenge addressed in the literature is the use of additives and pretreatments to ease decomposition and improve biogas production efficiency. It is concluded that significant improvements can be expected after pre-treatment to facilitate accessibility of microbes to the degradable substrates. In particular, anaerobic fermentation by rumen microorganism is suggested as a promising way for effective disposal and utilization of Typha and other aquatic plants.

In addition, the review on biogas digester design we found that at rural or domestic level, biodigestion in tubular digesters is recommended as the most appropriate and affordable technology for small scale production.

On other strand, the literature review revealed several pioneering works related to the use of Typha grass for animal feed. According to these studies we can conclude that the nutritive value of Typha forage is relatively low, although it can be improved with adequate treatments like wilting (hay) and ensiling (silage) when complemented with sugar molasses and urea. Moreover, these treatments also improve Typha preservation, which allows for future utilization when no pasture is available. Based on these initial studies it is preliminarily concluded that Typha may be a potential alternative source of forage near the wetlands.

The anaerobic conversion of cattail could be a promising source of biomass to produce clean energy and reduce pollution. The valorization of Typha for biogas could be an opportunity to turn a negative constrain for local populations into a clean source of energy for cooking and lighting. This is in line with the pillars of sustainable development and mitigates the effects of climate change.

The livestock industry in Nigeria is mainly composed of cattle; sheep and goat from farms are the main feeds for livestock. The shortage of feed in terms of quality and quantity especially during dry season is one of the most serious problems faced by farmers in the Northeast of Nigeria. In this context, to assess an animal feedstuff it is important to know its chemical composition of Typha plant. This plant, supplied entirely to animals, has a nutritional value in which its protein content stands out with average of 8% and the availability of fiber higher than 80% constituting a forage option for ruminant nutrition.

In the case of silage, it could be necessary to add molasses, which would favor the conservation of the dry matter and the content of soluble carbohydrates for fermentation. Also, it could be necessary the inclusion of urea. Also addition of enzymes can improve on the digestibility of Typha. Typha grass is an acceptable alternative source of forage near the wetlands that could be used to make quality silage to feed ruminant animals during the dry season.

Also, other uses of Typha has beethis aquatic plant shows potential to be used as a thermal insulation material. Its use could trigger the creation of small local business, while improving building and life quality of local communities too. It has to be noted that currently cattail is already used for traditional roofing material by Fulani local communities, artisanal items and for the transport of vegetables to local markets. Interesting uses have been reported in other areas such as culinary uses and its use in water treatment facilities

A review of other areas in West Africa where Typha is also a nuisance as it is the case of Senegal, provide interesting ongoing green charcoal projects based on Typha. These experiences will be further explored in subsequent stages of the Typha project since they may offer relevant lessons to ease adoption in the Typha project.

In light of the literature review we found evidence of the potential of Typha plant for the use of novel technologies for the economic conversion of Typha biomass into biogas and animal feed. The use of novel and unique technologies within the action research Typha project may contribute to bring to the Nigerian people an opportunity of transforming the invasive Typha weed into biogas to use locally in their communities. Also, it could develop as a raw material for animal feed, when harvested in early stages of plant growth of the plant or after ensiling to use during the dry season.

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