

Huquet Bérénice  
Lemaire Gaëlle

## Biogas experiments

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Supervisor teacher: Safia Menasseri from the ENSAR  
Training period referent: Dr René Haller from Baobab Trust

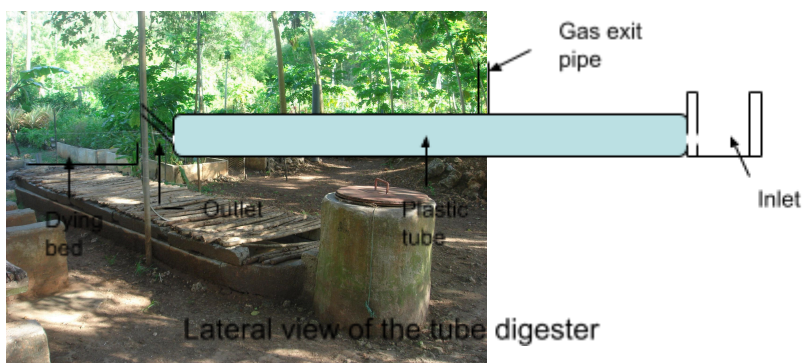
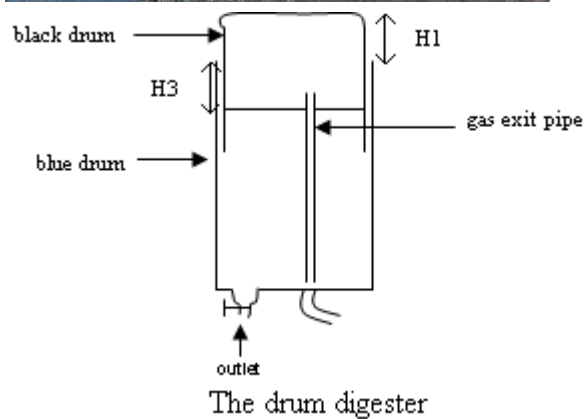
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The digesters were built 3 years ago, it has two goals:

- To make the farm autonomous about its gas consumption
- To find the best and the cheapest way for a Kenyan family to produce its biogas.

In order to try to answer to this aim, we have worked on the two kinds of homemade digesters. The first one is made with two drums and the second is the plastic tube:



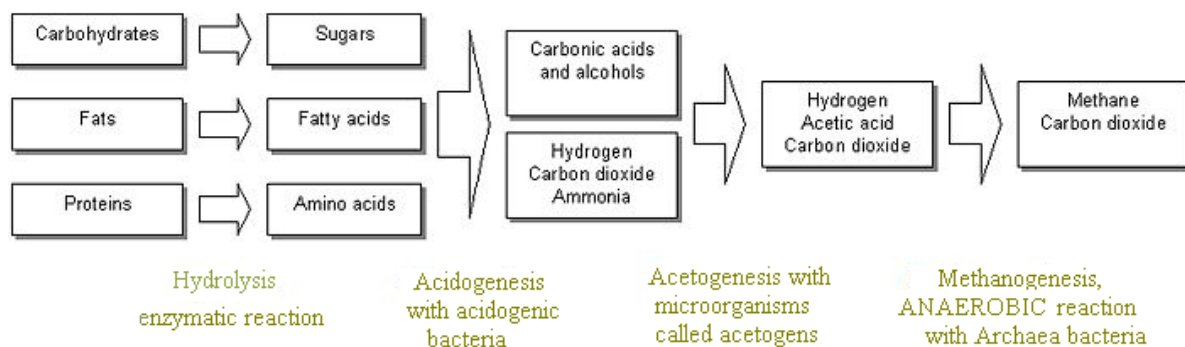
Lateral view of the tube digester

## I. The biogas

The biogas comes from the organic animal or plant fermentation without oxygen. It happens naturally in marshes and dumps and can be created in digesters. The most used digesters are mesophilic, it means that they work between 25 and 40°C.

The biogas is composed of methane (from 50 to 70%), carbon dioxide, water, H<sub>2</sub>S and other substances. The most important compound in the biogas is the methane because it can be used for different things but mostly for the combustion.

The methane is created during the anaerobic digestion which is composed of 4 different reactions:



### The four stages of the anaerobic digestion

A simplified equation for the overall process is:  $C_6H_{12}O_6 \rightarrow 3CO_2 + 3CH_4$

The use of the biogas takes part in the sustainable development: it limits the amount of methane that escapes in the air; the methane is 21 times less dangerous than the carbon dioxide for the greenhouse effect. Moreover the use of the biogas avoids the use of wood to cook so avoids the deforestation.

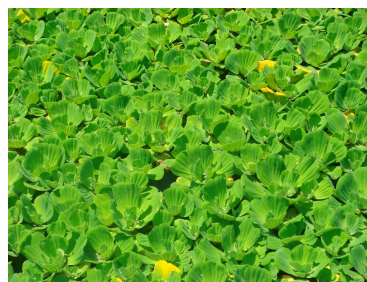
## II. Study about the raw materials

The aim of this experiment is to find the best raw material to produce biogas. We have tried 3 different raw materials: manure, Nile cabbages and a mix of the both.

### a. Nile cabbages description



*One Nile cabbage*



*A pond covered by Nile cabbage*

The Nile cabbages are floating water plants (*Pistia stratiotes*). They are found in the pounds or lakes (Victoria Lake). They cover all the water, it limits the evaporation but in the pounds where there are some fishes, it's important to pay attention that there are not too much Nile cabbages to avoid fishes suffocation.

This plant is a good indicator of the water quality: its roots are as long as the water is poor of nutriments.

They can be used for animal nutrition but on the farm they are dried and added to the compost to fertilize the ground. In ideal conditions, this plant grows quickly and may overrun the pound. That's why it could be another good material instead of the manure to produce biogas.

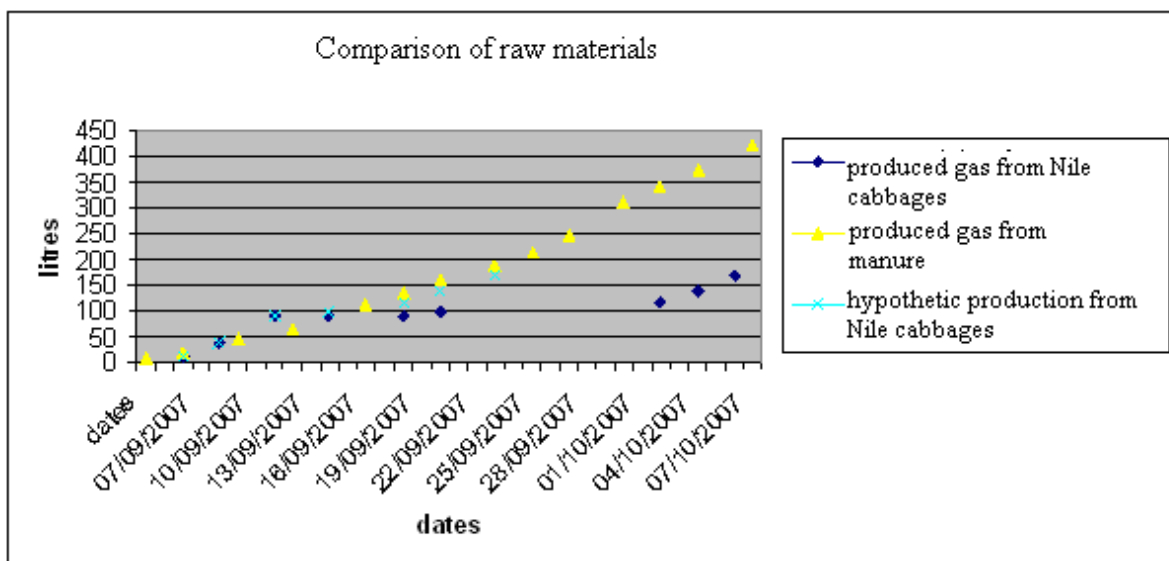
#### b. Protocol

We used the drums digesters in order to study them in the same time; like that they are always in the same climatic conditions.

*Beginning of the experiment:* 60 litres of water and 40 litres of liquid with bacteria (coming from another digester) are put in each digester. In the digester A, B and C, we add respectively 6kg of crushed Nile cabbages, 6kg of manure and 3kg of manure+3kg of Nile cabbages.

*Daily use:* every two days, we measure the high between the top of the black drum and the top of the blue drum (H1). We put a weight of 33kg on the black drum and we measure again the high between the two drums (H2). We open the tap, the gas escapes by the pipe until the stove where it is burnt. We note the time of combustion and we close the tap. Then we open the digester, we mix the liquid, we note the high between the liquid and the top of the blue drum (H3). We empty 20 litres. We add in each digester 6kg of their own raw materials and 20 litres of water, we mix and close the digester.

#### c. Results and analysis



*Hypothesis:* The air initially present between the liquid and the top of the black drum keeps its own volume during the biogas production.

With this hypothesis, we do an approximation in our calculations but it was difficult to know how the air is compressed by the produced biogas.

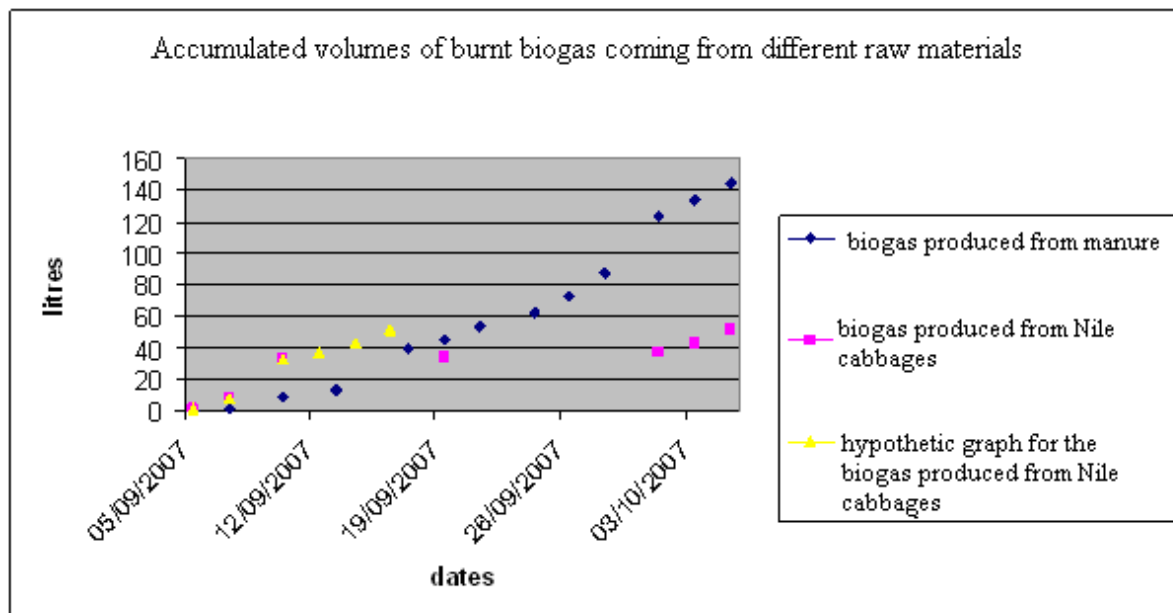
So we calculated the volume of produced biogas as if it was the same as the volume between the top of the black drum and the top of the blue one:

$V1 = \pi \times r^2 \times H2 \times 0,001$  with V1, the volume of compressed biogas (in litre)

r, the inside radius of the black drum (24,5cm)

H2, the height between the 2 drums under the pressure of a 33kg on the black drum

To calculate the volume of burnt biogas, we considered that the produced gas and the air which was initially present mixed. This hypothesis means that the gas which is burnt is a mixture of biogas and air, and that all the produced biogas isn't burnt (there is still a part of it under the gas exit pipe).



So the volume of burnt biogas was calculated with this formula:

$V2 = H2/(H2+H3) \times V3$  with V2, the volume of burnt biogas

H2, the height between the 2 drums under the pressure of a 33kg on the black drum

H3, the height between the liquid and the top of the blue drum

V3, volume of burnt gas (air + biogas) ( $V3=V1$ )

The biogas production from the manure seems to be constant: 13 litres of pressed biogas every day, it means a little more than 5 litres of gas produced per day and per kilogram of cow waste, it permits combustion during 1min20s If our protocol is respected, the cooking time is 4 minutes per day.

The Nile cabbages produced biogas at the beginning and at the end of the experiment. The first of October, we discovered a leak on the digester which explains that the digester hadn't produced for one week. After the repair, the production goes on. We drew a

new production graph as if there wasn't any problem. If we look at this graph, we can say that the Nile cabbages produce on average 8,5 litres of biogas per day, it means 2,5 litres produced per day per kilogram of raw material, it permits combustion during 30 seconds (average calculated from the total weight of cow wastes used during the experiment: 66kg, the total volume of produced biogas: 167 litres and the total time of combustion: 37min).

The gas production from a mix between manure and Nile cabbage is not on the graph. This can be explained by the fact that it was very little. This problem must come from a flaw in the used digester because a leak was observed in it and even after a repair, any experiment made in this digester worked.

Despite this technical problems and the use of a hypothetical graph, manure seems to produce more than Nile cabbages even if this production isn't considerable. However Nile cabbages produce a little gas, so we can think that in an other type of digester and in more considerable quantities they could be used to produce biogas for a family which doesn't own cows.

#### d. Comments

*General comments:* - The production could have been more important if we had used more raw materials, however the aim of the biogas production on the farm is to stay at a small scale in order to be applied at a Kenyan family home. So we have to pay attention of the possibilities of a standard family which has rarely more than two cows. That's why we have decided to use only 6kg of raw materials every two days.

- In order to avoid the formation of blocks, the manure has to be mixed very well with the 20 litres of water, the garbage (leaves, stones, wood...) have to be removed before pouring all in the digester.

- To compare the time of combustion, the stove has always to be switched on at the same level. We have chosen to switch on at the maximum level.

- The temperature can influence the bacteria activities so we have noted it every day in order to study its consequences. Unfortunately it didn't change a lot during our training period (more or less 1°C), so it's not possible to link the gas production and the temperature.

- This kind of digester is cheap but has got some faults: they are not entirely watertight, when it rains water can come in, and they can put out of shape themselves (after it's more difficult to put the black drum in the blue one).

*Comments on the protocol:* - To measure the volume of liquid, we have used buckets and a 1,5 litres container. The precision of our measurements is quite approximate because we noted 20 litres for one full bucket but there were some loss during the transport. The real volume which has been poured in the digester can vary from 17 to 20 litres. The precision of the weight was at more or less 500g because of the quality of the scales.

- The gas production from the Nile cabbage digester could have been more important because the crushed plants made a cake, which prevents a part of the gas from going up. To avoid this problem, we have put a stick of wood horizontally in the black drum; it permits to mix the liquid and the plants every day.

- The volume of produced gas can be under-estimated because 2 times, we forgot to close the tap so we lost some gas.

- At the beginning, we had some problem with the combustion. Some gas was going out of the stove but it burnt only if we let a match on it. In fact this

problem can be explained by a lack of pressure on the black drum during the combustion. So then we added some pressure on this drum and like that the gas burnt without any problem.

*Comments on the results:* - When the digester is closed (black drum in the low position), there is still a volume filled with air between the black drum and the liquid. During the gas production, the black drum goes up, the air and the produced biogas mix. So during the gas combustion, we burn only the mix of air and biogas which is above gas exit pipe, so a part of the produced gas isn't burnt. To calculate the volume of the burnt gas, we said that the volume of burnt gas was the one present between the top the black drum and the gas exit pipe but during the gas combustion the black drum didn't stop perpendicularly at the gas exit pipe.

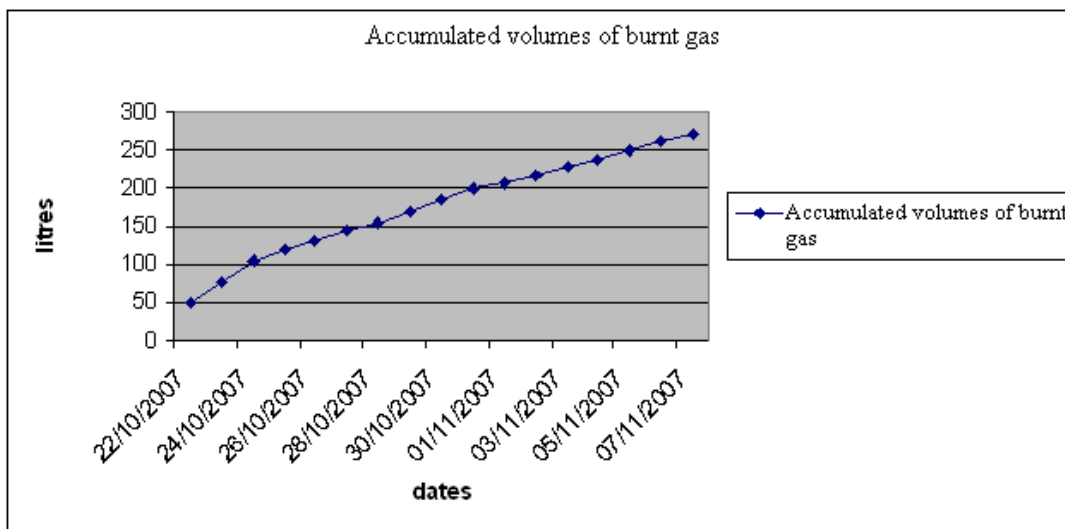
A family needs a cooking time of 45 minutes every day (2 traditional meals and one tea), which is not possible with our protocol. To obtain this production, the quantities of raw materials should be increased or we should use some better digesters.

In our protocol, we have taken some decisions (kilograms of raw materials, frequency of filling...) but in a real situation, it's possible that a family can't fill the digester like in this protocol. That's why we have done another experiment in order to know the maximal capacity of production with only one add of raw materials.

### III. Study about an only add of raw material

*Protocol:* In a digester which already produces (working bacteria) we add 6kg of manure and 20 litres of water. Then we measure every day the quantity of produced gas and the time of combustion without putting any new raw material in the digester. The experiment is finished when the gas production stops.

*Results and analysis:*



To calculate the volume of burnt gas, we used the same formula as in the experiment on the raw materials.

. Cette modification du protocole allègerait la quantité de travail à fournir.

The production decreases during the experiment: at the beginning, the cooking time was around 5 minutes but at the end it was only 3 minutes. Despite the decrease, the cooking



time, at the end of the experiment, is quite the same as the one we had in our first experiment with regular adds. So a Kenyan family could produce biogas adding manure less often (every week for example). This modification of the protocol could alleviate the quantity of work.

*Comment on the material:* The problems we had are the same as in the first experiment (quality of the digester)

NB: We wanted to do the same experiment with the Nile cabbages but some technical problems prevented us from quantifying the production. We have even so seen that after one week the Nile cabbages were still producing some biogas. This observation makes us think that the new protocol could be apply for this raw material even if it would be better to repeat this experiment.

#### IV. Comparison of two kind of digesters

In the experiment on the raw materials, we saw that the production in the drum digesters was slight even the one from the manure which is often used to produce biogas. We wondered if it was because of the kind of digesters.

Moreover when we used the drum digesters, we came aware of the difficulties to use this kind of digesters (to lift the black drum, to raise the bucket above the digester which is high, to pay attention to not introduce some materials in the gas pipe). That explains why they are used only for experimentation.

Does this kind of digesters produce as much as the tube digester (which is the most likely used by a Kenyan family) even if they have some faults?

*Protocol:* We use the tube digester which is already working. Every two days, we add 6kg of manure, 20 litres of water and we remove 20 litres of liquid by the outlet. The gas is sent to a storage which was emptied before the beginning of the experiment.

*Comments:* At the end of our training period, the gas storage was not completely full. So it was impossible to quantify the volume of produced biogas and we compared the two digesters on the cooking time.

*Results and analysis:* two weeks after the beginning of the experiment on the tube, we burnt the gas from the storage. The cooking time was 1h17 which corresponds to 1minute50seconds per kilogram of raw material (42 kg of raw material were used during this experiment). If we compare this time with the one we had with the drum digesters (1min20s), we can assert that the tube digester is more productive.

*Comment :* The main fault of the tube digester is the conception of the gas storage. When the storage is full the escapes easily and produces big flames on the stove; but when the storage is almost empty, the system to make the gas escape doesn't put the gas under a sufficient pressure to produce big flames. To improve the conception of the storage, all the storage would have to be under the same pressure (to avoid that a part of the bags are not under the railings any more). It could be interesting to build some walls around the storage in order to keep the bags in a definite space.

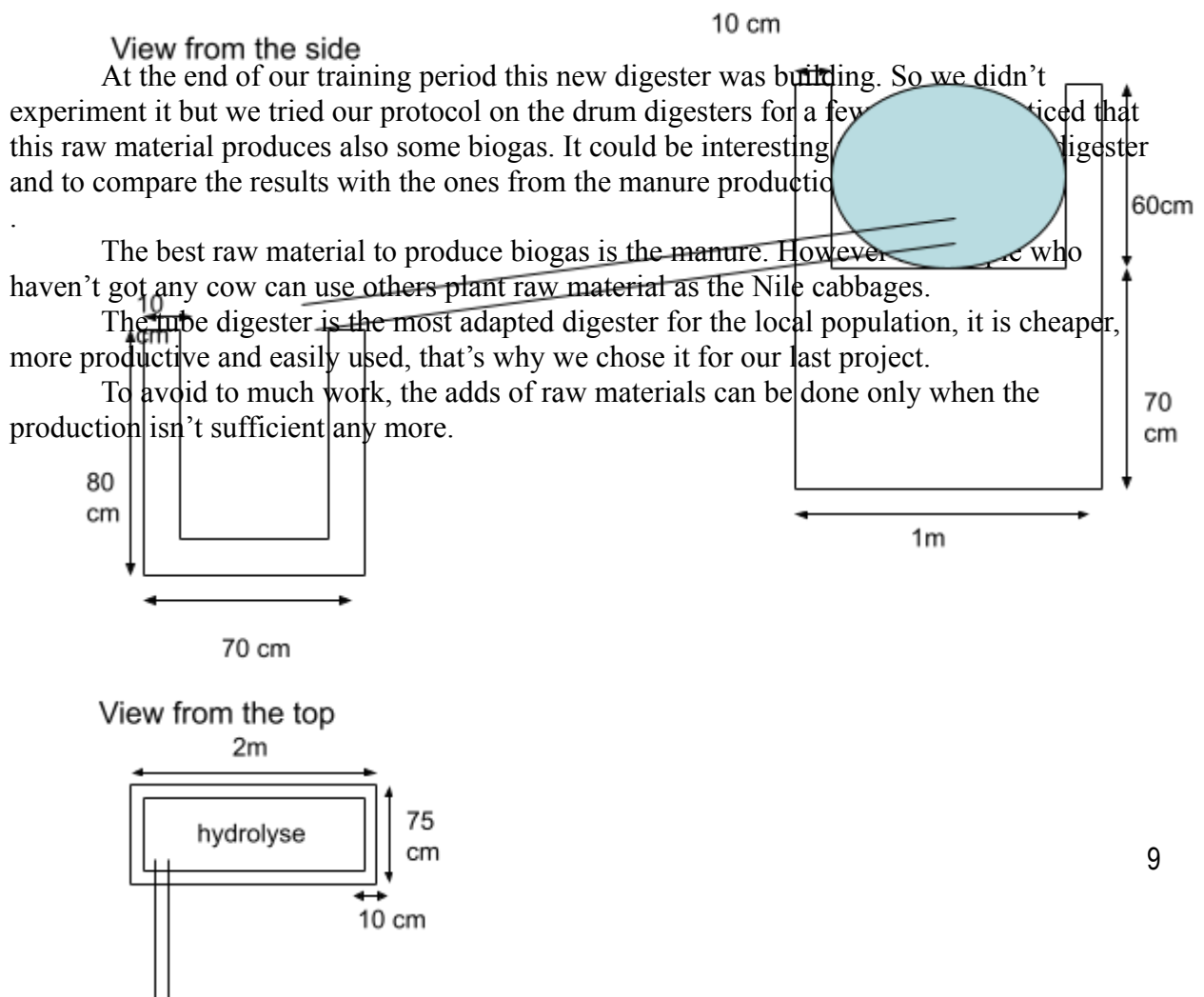
The drums digesters are not convenient, get damage faster (the taps get rusty, the plastic put out of shape itself, can crack and create some leak) and are more expensive to build and to maintain than the tube (around 2 500Ksh for one drum digester against 1 000 for the tube). Another advantage of the tube digester is that all the produced gas can be used unlike the gas produced in the drum digester. That's why we advise the tube digester for a daily use. However the tube needs to be maintained: after a while sedimentation happens in the tube and it limits the production capacity of the digester. But the cleaning of the tube on the farm was useful only after 3 years of utilisation.

## V. Project on a new production system

During our study on the raw materials, we noticed that the gas produced by the Nile cabbages was a worse fuel than the one produced by then manure. This fact could be explained by a higher concentration of carbon dioxide in biogas produced by the fermentation of Nile cabbages. To try to resolve this problem, the anaerobic digestion reactions which create carbon dioxide have to be realized out of the digester. This hypothesis and the meeting with the manager of Go Kart make us imagine a new digester with works with a raw material which has lost all the carbon dioxide.

We let some vegetables and plants in water during a few days, the first stages of the anaerobic digestion happen and the carbon dioxide goes in the air. We use the water in which were the plants as a raw material for the digester (the problem of cake is avoided). To avoid wasting water, the liquid coming from the outlet will be recycled for the bath of the plants. For a simpler use of the hydrolysis container, we will put in it a bucket with holes in order to remove the vegetables.

This new digester will be a tube one because it is the cheapest and can be easily home made.



Thanks:

- to M. Haller to have shown us a new type of agriculture
- to Sonal to have helped us in the daily life
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