Interreg – IPA CBC

EUROPEAN UNION

CCI 2014 TC 16 I5CB 009

ZEFFIROS

Zero-waste energy-efficient agricultural communities in the Greece-Republic of North Macedonia cross-border area - ZEFFIROS

DELIVERABLE 3.3

Guidelines for effective bio-waste management

12/2019

Sub-Deliverable 3.3.3 – Rules, Operations, Supplies, Management and Measures for compliant and efficient slaughterhouse waste feed for bio-gas production

Authors: SFADIS personnel: Elena Malioka (Food Safety expert), ENERVIS (as SFADIS sub-contractor)

Project co-financed by the European
Union and National funds of the participating countries

Table of contents

1. Introduction

Meat is considered one of the most important elements in the diet of people of all ages with significant nutritional value. A great part of the meat production process takes place in special facilities called slaughterhouses. However, besides the meat produced, the waste resulting during slaughtering also constitutes slaughterhouse product. This waste, if not properly treated, can cause serious problems in the environment where it is disposed. This is due to the rich organic content of that waste, which is difficult to biodegrade; consequently, this waste needs further treatment before its disposal.

The present sub-deliverable briefly presents the procedures followed in the SFADIS slaughterhouse, gives an outline of the regulations complied with and analyses its capacities and the types and quantities of bio-waste it produces for possible further processing with a target of their exploitation instead of their simple disposal and/or incineration. It also describes model procedures to be followed for the effective supply of valid and beneficiary SHW types to the Serres Municipality pilot biogas-unit for the efficient treatment of this waste along with waste of other agro-industries with the aim of biogas and fertilizer production via Anaerobic Digestion (AD).

2. Municipal bio-gas unit in Serres and Slaughterhouse (SHW) bio-waste for processing.

2.1. Short description of SFADIS slaughterhouse activity

SFADIS Slaughterhouse (SH) is installed in Neos Skopos, 10 km away from the city of Serres. The unit operates complying with the provisions of the Commission's regulations No 852/2004 on the hygiene of foodstuffs and No 853/2004 laying down specific hygiene rules for food of animal origin.

The unit processes the following livestock categories:

- Calf
- Pigs
- Lambs
- Sheep

The unit's annual processing capacity during the last 5 years is depicted in the following table.

Table 2.1: Slaughterhouse unit's annual processing capacity

Livestock (units)	**2015**	**2016**	**2017**	**2018**	**2019 *(as of September)***	**2019 *(Projection)***
Calfs	708	1.191	1.487	1.444	1.160	1.566
Pigs	4.864	4.486	7.272	7.422	5.281	7.518
Lamb	10.726	8.412	9.859	10.531	8.030	10.246
Sheep	374	548	976	1.089	729	1.132
Total *(in tn)*	**596**	**702**	**899**	**979**	**740**	**1.020**

The unit occupies personnel consisting of 8 persons responsible for different functions of the everyday slaughter process and at least one veterinarian is present during the working hours for quality assurance purposes regarding compatibility with the provisions of the Commission's regulation No 853/2004 and specifically the check and characterization of by-products which have to be incinerated or be disposed by certified entities and are considered dangerous and/or potentially dangerous for human consumption, suspicious and/or infected. Dangerous and/or potentially dangerous for human consumption by-products are classified in Category 1 as per the Commission's regulation No 1069/2009 laying down health rules as regards animal by-products and derived products not intended for human consumption. For the types of livestock processed, such by-products are the following:

Category 1 SFADIS SH animal by-products:

- Entire dead bodies of animals as may happen to be present during delivery and before entering the slaughter process
- Animals and parts thereof suspected of being infected by a transmissible spongiform encephalopathy (TSE) in accordance with Regulation (EC) No 999/2001 or in which the presence of a TSE has been officially confirmed.
- By-products containing residues of other substances and environmental contaminants listed in Group B(3) of Annex I to Directive 96/23/EC, if such residues exceed the permitted level laid down by Community or National legislation
- Breast (of female animals)
- Intestinal tract from the duodenum to the rectum
- Spinal cord (for animals older than the age of 12 months)
- Spine (for animals older than the age of 30 months)
- Skull except from the lower jaw
- Brains
- Eyes

- Tonsils

Other by-products as resulted by the unit's everyday activity include the following as they are classified to Categories 2 and 3 as per the provisions of the Commission's regulation No 1069/2009:

Category 2 SFADIS SH animal by-products:

- Suspicious for health reasons carcasses or organs as those may be characterized by the shift veterinarian
- Stomach and intestinal content

Category 3 SFADIS SH animal by-products:

- Extremes (legs)
- Horns
- Blood
- Skins
- Fats

Commission's regulation No 1069/2009 permits the exploitation of by-products belonging to Category 2 and Category 3 by-products via conditions and processes defined/recommended in Commission's regulation No 142/2011 implementing regulation No 1069/2009 mainly for purposes of natural fertilizer production and energy recovery including bio-gas production and its further usage.

2.2. Annual production of SH by-products

In every step of the slaughter process, specific procedures are taking place in order to properly remove, collect and store Categories' 1, 2 and 3 by-products. Each different by-product is stored in labelled bins possessing distinct characteristics (e.g. color) per by-product. The practice followed until today includes the delivery of all stored by-products on-site to collaborating certified entities responsible for their further disposal except the "Stomach and intestinal content" Category 2 by-product. This is left in batches in atmospheric conditions in order to be completely dried and then it is delivered to local interested farmers for soil conditioning purposes.

The overall disposal practice currently followed bares the SFADIS's slaughterhouse operation with high costs both in economic and handling terms. The economic burden stems primarily form the costs of contracting certified entities for by-products belonging to all categories. Regarding handling terms, this especially concerns the handling of the "Stomach and intestinal content" Category 2 by-product, whose delivery to farmers is not always guarantied and as a consequence, the unit is enforced (after drying) to load and transfer it to a landfill at its own costs.

The following table 2.2 depicts a representative outline of the annual production of animal by-products produced and delivered for the operational year 2018.

Table 2.2: Slaughterhouse unit's 2018 by-product production outline

2018	Calf Intestine & Stomach content (kg)	Pig Intestine & Stomach content (kg)	Calf Cat.III (kg)	Pig Cat. III (kg)	Sheep Cat. III (kg)	Lamb Cat. III (kg)	Skulls (kg)	Blood (kg)	Calf Intestines (kg)	Pig intestines & stomachs (kg)	Sheep & Lamb intestines & stomachs (kg)
January	3.633	6.334	616	1.884	560	240	560	1.344	2.240	1.747	210
February	2.335	5.487	396	1.632	216	359	360	864	1.440	1.514	81
March	3.276	6.357	556	1.891	80	762	505	1.212	2.020	1.754	30
April	3.211	7.250	545	2.156	92	1.591	495	1.188	1.980	2.000	35
May	4.573	5.986	776	1.780	596	243	705	1.692	2.820	1.651	224
June	4.022	6.484	682	1.929	276	179	620	1.488	2.480	1.789	104
July	4.768	7.749	809	2.305	256	171	735	1.764	2.940	2.138	96
August	3.892	7.053	660	2.098	328	131	600	1.440	2.400	1.946	123
September	3.957	7.447	671	2.215	340	65	610	1.464	2.440	2.054	128
October	4.995	7.285	847	2.167	636	114	770	1.848	3.080	2.010	239
November	3.211	6.670	545	1.984	388	86	495	1.188	1.980	1.840	146
December	4.962	11.994	842	3.567	588	797	765	1.836	3.060	3.309	221
TOTAL:	**46.835**	**86.095**	**7.942**	**25.606**	**4.356**	**4.739**	**7.220**	**17.328**	**28.880**	**23.750**	**1.634**

3. Procedures for SHW substrates supply to the bio-gas unit

3.1. Laying down procedures followed along slaughtering

The schematic in Figure 3.1 depicts the overall process followed during the day-to-day activity of the SFADIS slaughterhouse unit. The process was studied and mapped, indicating both the basic production process (on the left side of the schematic), as well as the processes followed to cope with the produced animal by-products (right side of the schematic). Animal by-products as they are resulted by the main slaughtering process are categorised according to classification dictated by the Commission's regulation No 1069/2009 laying down health rules as regards animal by-products and derived products not intended for human consumption. The slaughtering process depicted is based on and completely satisfies the provisions of the Commission's regulations No 852/2004 on the hygiene of foodstuffs and No 853/2004 laying down specific hygiene rules for food of animal origin. In Figure 3.1, designated in green color are parts of the animal by-product's management processes that are corresponding to the internal (inside the slaughterhouse's facility) management of such by-products which are deemed valid and beneficial for further processing for the purpose of bio-gas production under Anaerobic Digestion (AD) conditions.

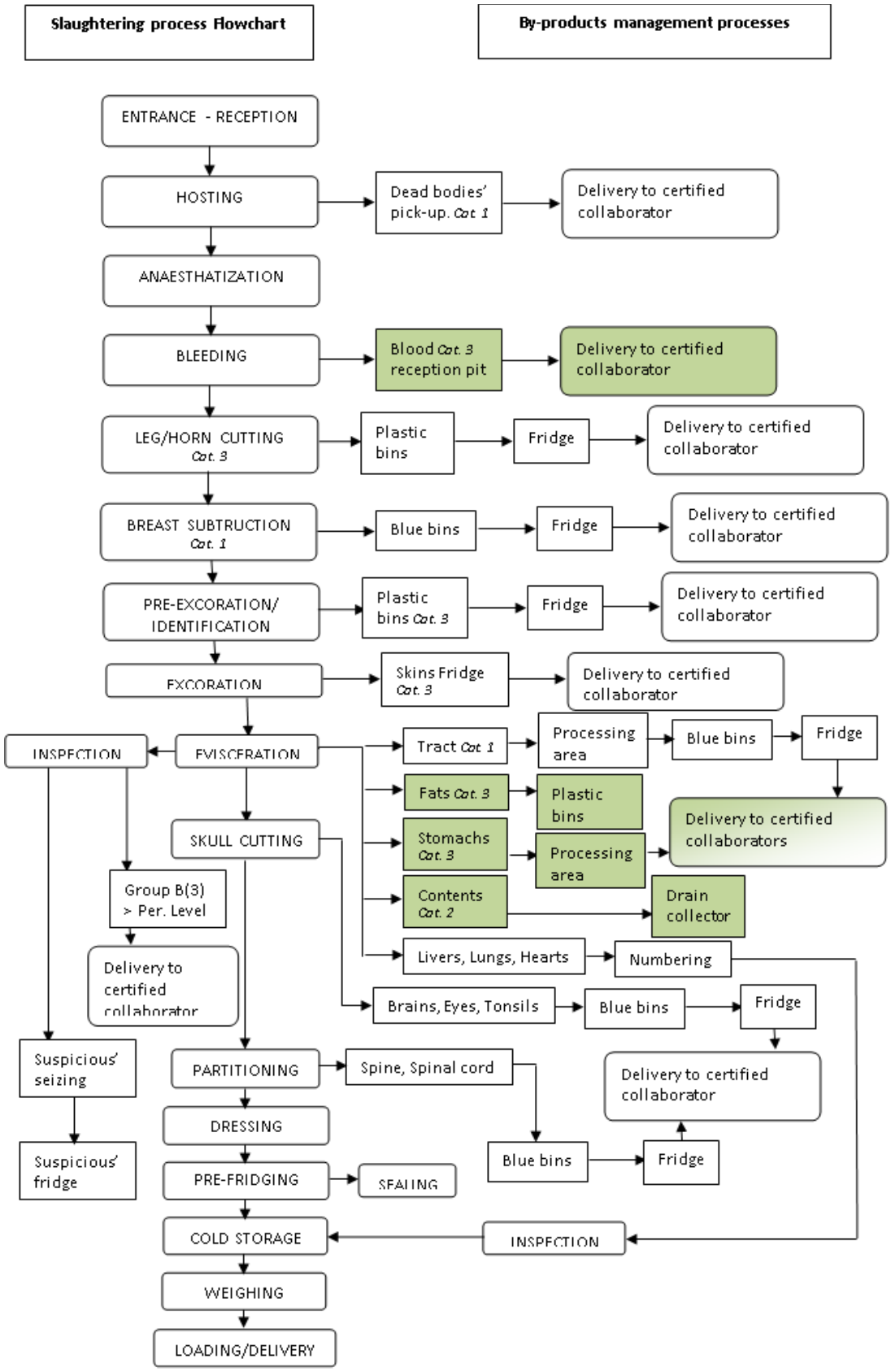

Figure 3.1. SFADIS's Slaughtering process and AD intended by-products' process routes

3.2. By-products as substrates suitable for anaerobic digestion (AD) and planned annual supplies

Past experience has proven that slaughterhouse waste (SHW) is a very energy-rich waste stream of meat industry (Edström et al. 2003). As such, it is an attractive material to treat through anaerobic digestion for the production of biogas, especially under co-digestion with other bio-waste substrates stemming from agricultural and food processing industrial activities. Literature as well as recently followed practice suggest that under relevant regulative procedures, intestinal content, as belonging to Category 2 (as per Regulation 1069/2009) animal by-products and stomachs, fats and blood, as belonging to Category 3 (as per Regulation 1069/2009) animal by-products offer increased capacity for biogas production when co-digested with livestock manures, crops-based agricultural products and residues (e.g. corn silage) and residues from food processing activities (e.g. whey from cheese production) (Al Seadi et al. 2010).

Table 3.1 shows a comparison of the methanogenic, as the active part of bio-gas production's capacity, of the relevant SHW residues to the methanogenic capacity of liquid cow manure.

Table 3.1: Comparison of AD properties of produced SHW substrates with those of cow manure

Substrate	Dry Matter (%)	ODM (%)	Biogas (m3/tnFF)	Methane (%)	Methane (m3/tnFF)
Intestine content	15	84	61.11	60	36.67
Stomachs & Fats	20	90	72.00	60	43.20
Blood	18	96	59.27	70	41.49
Liquid Cow manure	10	80	25.00	56	14.00

In the table above, Dry matter stands for the percentage of dry matter in a mass quantity of reference of Fresh Feed (FF) of the substrate under examination, while ODM stands for the percentage of organic matter contained in the dry matter. In fact ODM represents the fraction of the dry matter that may be converted to energy via biogas production. Alternatively, this fraction expresses the percentage of the volatile solids (VS) of the dry matter, which is the fraction responsible for biogas production in anaerobic conditions. It is evident from Table 3.1, that indeed, SHW substrates corresponding to the ones produced in SFADIS unit are ideal for co-digestion with e.g. liquid cow manure as it could introduce to the AD mix a part of more than double biogas production capacity with considerably higher methanogenic ability per tonne of Fresh Feed as compared to liquid cow manure. It should be noted that methane is the part of biogas produced from the AD process that it can be burned in an Internal Combustion (IC) engine (or a Combined Heat & Power – CHP unit) and as such, it is the part of biogas that can produce useful energy in the form of electricity and heat.

It should be noted that classified as Category 1 by-products produced in the SFADIS unit are not eligible for AD processing or for any other kind of exploitation. By-products classified as Category 3 ones excluding stomachs, fats and blood, i.e. horns, extremes and skins are not valid AD substrates as they cannot be shredded on-site so as to become pump-able and reach fault-free pumping rates for feeding anaerobic digesters.

The processing of the annual SHW quantities produced by the SFADIS's slaughterhouse unit operation for the year 2018 as well as of the corresponding ones from January until September for the year 2019 has revealed that that SFADIS can supply the following SHW types and quantities to the Serres pilot bio-gas unit on a yearly basis.

Table 3.2: SFADIS yearly supplies to the Serres pilot bio-gas unit

Substrate	tonnes/Year
Intestine content - *Cat. 2*	150
Stomachs & Fats - *Cat. 3*	13
Blood - *Cat. 3*	18

Under the assumption that a CHP unit is working at 40 kW_{el} with a yearly availability of 56%, the latter annual quantities with respect to the properties provided in Table 3.1 are able to contribute annually the following quantities of biogas and methane in m^3, respectively.

Table 3.3: SFADIS's supplies yearly contribution to the annual bio-gas production of Serres pilot unit

Substrate	Biogas (m3)	Methane (m3)
Intestine content - *Cat. 2*	9,150.00	5,490.00
Stomachs & Fats - *Cat. 3*	916.67	550.00
Blood - *Cat. 3*	1,085.71	760.00

3.3. Supplies management and control procedures

SFADIS has designed and is proceeding to the construction of a room as an extension of the existing facilities, dedicated to the processing, separation, collection, packaging and temporary storage of animal by-products resulted from the operation of the slaughtering unit. The room will occupy a surface of 50 m^2 and will be equipped with state-of-the-art washing systems and drainages, as well as with ventilation/air conditioning system preserving a constant temperature of no more than 7° C inside the room, all ensuring compatibility with Commission's regulations No 852/2004 and No 853/2004. According to the process depicted in Table 3.1, Cat. 3 - Blood by-product is collected into a blood reception pit of volume 20 m^3 where it is stored until delivery via pumping a tank truck of the responsible certified collaborator. Cat. 3 – Fats by-product is separated and collected into plastic labelled bins of volume of 0,44 m^3 each. Cat. 3 – Stomachs by-product is also separated and collected into plastic labelled bins of volume of 0,44 m^3 each. As per Cat. 2 – Intestines content by-product is acquired through the washing processes and is collected via drainages in semi-liquid form in a central drainage-ending space (collector) from which it is picked-up and currently unloaded in batches at open space for drying purposes before local farmers pick it up for soil conditioning purposes. As it is depicted in Table 3.1, this Cat. 2 by-product, as possessing highly valuable properties in an AD co-digestion process, is suggested to be pumped fresh by a pump-carrying tank truck from the drain collector in order to be transferred to the Serres bio-gas pilot unit.

Pre-delivery procedures

The overall pre-delivery, before transportation, procedure to be followed on behalf of SFADIS slaughtering unit after collection, separation and packaging of the by-products of interest is suggested to include labelling, documentation and temporary storage classification.

1. **Labelling**
   Each plastic bin to be labelled with a stamped tag indicating:

- By-product's name and Category classified
- Date of packaging
- Proper delivery lot numbering

2. Documentation

Each lot of labelled by-products packaged should be accompanied by a shift veterinarian's certificate including approval of negative findings of the relevant inspection, including the date of inspection.

SFADIS's administration will prepare per each delivery lot of packaged labelled by-product an accompanying document describing:

- Total number of bins per delivery lot
- Date of delivery

3. Temporary storage classification

Each delivery lot prepared should be temporarily stored pre-delivery under the same temperature conditions as the ones corresponding to the processing temperature (i.e. up to 7° C). The bins corresponding to each delivery lot should be arranged in such a manner in order bins of the same delivery lot to be aggregated in an easily recognized space per delivery lot inside the by-products' processing room.

Transportation

Transportation of the by-products to the Serres bio-gas pilot unit is suggested to be performed via tank trucks blood and Intestinal content and a cold storage bin-carrying truck for fats and stomachs. The type and kind of the latter truck has already been identified by SFADIS's management and will be shortly procured and purchased. It will contain a storage volume of c. 12 -15 m^3. Cat. 3 - Blood by-product is suggested to be transported via trailer tanks of 500 lt carrying volume, while Cat. 2 - Intestines content is suggested to be transported via trailer tanks of 2.000 lt carrying volime. Cleaning of the cold storage's bin-carrying truck will be under the responsibility of SFADIS, while washing of the tanks will be under the responsibility of the corresponding SFADIS's leasing partner.

Each delivery trip will be accompanied by a representative of SFADIS's staff and preferably by the person responsible for the deliveries of the unit's by-products to its certified collaborators. The cold storage bin-carrying truck should possess capacity to produce records of the temperature conditions during the trip. Temperatures of no more than 7° C should be recorded. At delivery, temperature's history along the trip should be added in the documents of delivery. It is expected that due to the fact that Serres bio-gas pilot unit is located in close vicinity to the SFADIS's unit each go and back trip for delivery will not last more than 1 hour in total, including unloading.

Delivery and schedule of deliveries

At the end of each trip, SFADIS's representative will supervise the unloading processes and deliver to the pilot bio-gas unit's representative the documents accompanying each lot of labelled bins including the shift veterinary's certificates for all by-products delivered.

The tanks carrying the blood and/or Intestinal content will be unloading the fresh matters via pumping towards the connection valves of a closed reception pit inside the bio-gas unit's site as it will be indicated by the bio-gas unit's representative. Labelled bins will be unloaded from the cold storage bin-carrying truck in front of the same reception pit and then, each bin will be emptied in the opening of a shredder mounted on the top of the reception pit to render the matter pumpable for feeding into the digesters (< 12 mm diameter). Each emptied bin will be closed again and will be reloaded empty into the cold storage bin-carrying truck until all the empty bins are reloaded. Washing of the bins will be under the responsibility of SFADIS, while washing of the shredders after emptying will be under the responsibility of the Serres pilot bio-gas unit. Emptying of the bins into the shredder's opening will either take place manually or via use of special lifting and emptying lifting mobile equipment (Clarks). The choice is depended on the final design of the bio-gas pilot unit. If proper earthworks are feasible for the construction of the reception pit semi-buried in a way that a certain perimeter is at low height, then emptying will be taking place manually. If not, the emptying will be taking place via the use of lifting Clarks.

According to the yearly supplied quantities given in Table 3.2 and given the fact that for an as much efficient as possible AD process to take place, the substrate matters must be received as fresh as possible, the following delivery schedule is foreseen:

Table 3.4: SFADIS's supplies yearly delivery schedule

Substrate	Deliveries/Week	tonnes/Delivery
Intestine content - *Cat. 2*	2	1.440
Stomachs & Fats - *Cat. 3*	1	0.245
Blood - *Cat. 3*	1	0.352

noting that a year contains c. 52 weeks. Intestinal content's delivery is suggested to take place every Monday and Friday, Blood's delivery on Wednesdays, while Stomachs' and fats' delivery on Fridays (National holidays excluded).

Delivery costs involved

Deliveries' activity involves no dedicated labor costs for SFADIS. Load and unload/ bin emptying operations of the owned cold storage bin-carrying truck will be carried out by SFADIS's personnel accompanying the truck in every trip. Costs involved in the suggested delivery procedures concern fuel cost of the owned cold storage bin-carrying truck corresponding to the yearly trips of delivery and the cost of the leasing service of the trailer tanks for Intestinal content and blood deliveries which is also calculated as the yearly trips' fuel cost plus an indicative 30% margin for the service provider. Valve connection and pumping to and from the trailer tanks will be operated by the trailer tanks' drivers/operators. The following Table 3.5 resumes calculations of the estimated additional yearly cost of deliveries for SFADIS.

Table 3.5: SFADIS's additional yearly cost of deliveries calculation

Delivery vehicle	trips/Year	km/trip	Consumption (lt/km)	km/Year
Cold storage bin-carrying truck	52	12.00	0.39	624.00
Trailer tank truck (500 lt)	52	6.00	0.39	312.00
Trailer tank truck (2.000 lt)	104	6.00	0.39	624.00

Total Cons. (lt/Year)	€/lt	Total Fuel (€/Year)	30% margin (€)	Total (€/Year)
244.71	1.35	330.35		330.35
122.35	1.35	165.18	49.55	214.73
244.71	1.35	330.35	99.11	429.46

It is estimated that the yearly additional cost of by-products deliveries to the Serres pilot bio-gas unit for SFADIS will be c. € 1.000.

3.4. Issues and measures for maximizing bio-gas production during anaerobic digestion

Anaerobic digestion of organic material is a complex microbiological process requiring the combined activity of several groups of microorganisms with different metabolic capacities which need to work in a synchronized manner in order to obtain a stable biogas process. One type of key organisms are the methanogens, producing methane mainly from acetate or hydrogen and carbon dioxide. Protein-rich substrate, such as slaughterhouse waste, is a well-known source of sulfide formation during anaerobic degradation. The increased concentration of sulfides in the digester lead to higher concentrations of corrosive H_2S in the biogas and can further lead to sulfide inhibition of the methanogens. When the proteins in slaughterhouse waste are degraded, not only sulfides are formed but also ammonia. The released ammonia increases the pH in the digester and with a large ratio of slaughterhouse waste in the substrate mixture, the pH tends to reach over 8.0, which can be growth limiting for some methanogens. The above optimal pH, together with a high fermentation rate of proteins and fats in the slaughterhouse waste can lead to an accumulation of fatty acids. Thus, if the organic load to the digester is not decreased at that point, the process overload can lead to increasing concentrations of process inhibiting fatty acids, the consequential pH drop and finally to a total inhibition of methanogenesis and process collapse will follow.

Fortunately, this is not going to be the case as far as it is concerned with the planned operation of the Serres pilot bio-gas unit, since co-digestion is foreseen together with liquid and dry manures, whey from cheese production and pulps from potato processing and olive mills operation. In fact the percentage of participation of fresh matter corresponding to SFADIS's by-products in the overall yearly mix of fresh matters under anaerobic digestion in the Serres pilot bio-gas unit is only 5,5 %. However, methods to lower ammonia levels in anaerobic digesters treating high-protein substrates are desirable. Furthermore, at increased pH and temperature, the equilibrium is shifted towards the toxic ammonia, resulting in a positive correlation between toxicity effects and increasing pH and temperature. Among the methanogens, the acetate-utilizing methanogens have been suggested to be responsible for 70-80 % of the methane produced. Experience however (Schnurer et al 2008), suggests that an alternative methane producing pathway is activated at elevated levels of ammonia. In this pathway, acetate is converted to hydrogen and carbon dioxide by syntrophic acetate oxidizers (SAO), followed by the subsequent reduction of carbon dioxide to methane by hydrogen utilizing methanogens, *i.e.* by this pathway methane is produced by hydrogenotrophic

methanogens only. Development of SAO has been shown to occur due to a selective inhibition of acetate-utilizing methanogens by ammonia, released *e.g.* during the degradation of proteins.

Relevant possible measures during AD for stabilization and methanogenesis increase

Controlled addition of ferrous chloride: Sulfide-associated problems, such as corrosive H_2S in the biogas and sulfide-inhibition of the methanogenesis are both reduced by precipitation of sulfides with Fe(II). The addition of ferrous chloride to the reception pit may result to reduced sulfide concentration in the digesters and the concentration of H_2S in the biogas should the monitoring of the properties of the digestion mix and the analysis of the biogas composition, respectively require such corrections. The same may happen as per the sulfur load on the water scrubbers to be applied in the pilot bio-gas unit. The possible H_2S-induced odors around the reception tank will be also reduced in this way.

Controlled addition of hydrochloric acid: Laboratory tests, with addition of hydrochloric acid to co-digestion reactors operated under mesophilic conditions (Ejlertsson 2005) shown positive effects on volumetric gas production and VFA levels were noted in the digesters where pH was lowered with hydrochloric acid. In practice, the following positive effects may take place: a) the digesters' loading rate could be increased by c. 70 % on VS (ODM) basis, b) increased bio-gas production may be observed, c) acetate concentration may be decreased by c. 40 % and d) partial alkalinity concentration may be increased by c. 6.000 mg/L. Overall, posible gas production increase will be a result of the increased loading rate since the specific methane yield per kg VS will remain unchanged.

References

Edström M., Nordberg Å., Thyselius L. Anaerobic treatment of animal byproducts from slaughterhouses at laboratory and pilot scale. Applied Biochemistry and Biotechnology, 109 (13), 2003, pp. 127 - 138.

Teodorita Al Seadi, Dominik Rutz, Heinz Prassl, Michael Köttner, Tobias Finsterwalder, Silke Volk, Rainer Janssen, «Biogas Handbook», University of Southern Denmark Esbjerg, 2010.

Schnürer A. and Nordberg Å. Ammonia, a selective agent for methane production by syntrophic acetate oxidation at mesophilic temperature. Water Science and Technology 57 (5), 2008, pp. 735 - 740.

Ejlertsson J. (2005). Swedish Patent No SE 525 313.

Authors: Elena Malioka, Ioannis Agnantiaris

Contact details: sfageioneouskopou@gmail.com, +30 23210 31300

Organisation: ΣΦΑΔΗΣ ΑΕ ΟΤΑ