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A CASE STUDY ON LIVESTOCK WASTE MANAGEMENT: JUNCOSA DE LES GARRIGUES (CATALONIA, SPAIN)

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In memoriam

This paper is dedicated to the memory of Mr. Antoni Grau, director of the Patronat de Promoció Econòmica of the Exma. Diputació de Lleida, who died in a car accident on the 5th August 1999. He put lots of energy in opening the way for this kind of studies.

Abstract

The objective of the present work was to characterise the cattle wastes, produced by some 10,000 animals, in the municipality of Juncosa de les Garrigues (Catalonia, Spain); to stablish the mass balance between nutrient production and extraction by crops in the area; to calculate the necessary storage capacity in order to adequate the continuous waste production to the seasonal crops requirements and, to evaluate treatment technologies (anaerobic digestion at laboratory scale, and composting at pilot plant scale) to increase the economic value of these wastes and to improve their fertilising quality. An additional objective was to define a general and structured method to design management programs of livestock wastes.

There is no excedentary nutrient generation as livestock waste in the municipality of Juncosa de les Garrigues. However, if all the waste is to be used in the studied area, the storage capacity of this waste must be increased from 4.3 to 8 months. If part of the waste is to be sold in the organic fertilisers market, composting is preferred to anaerobic digestion, because of the smaller water requirement and the smaller investment needed.

Key-words: livestock waste, management, composting, anaerobic digestion.

Introduction and objectives

As Prof. Taiganides (1998) explains in one of his funny stories, pollution is being created when something is thrown away and nobody picks it up to use it again. A thrown away residue will pollute when disregarded in an amount larger than the carrying capacity of the environment for that residue. If the environment (soil, water or air) can use the residue (or in the case of an organic residue its water, its energy, or its nutrients can be used) then that residue is valorised by re-use (recycling into the production system). Any resource must be managed in such a way that any discarded material is re-used by nature or other people, crops or animals.

Depending on the adopted criterion (quantity, nitrogen content, odour, ...) to give a value to a potential resource, a material will be a resource (product) or a residue (by-product). The resources are given high political priority, while residues (wastes) are neglected. However, if resources are neglected, they also become a residue. On the other hand, residues placed where they might be used, become a resource (for example, manure is a resource to the plants on crop fields). Therefore, it is not its intrinsic quality, but rather the priority given to it which makes a resource become a waste, and a waste become a resource. Wastes are resources out of place (Taiganides, 1998).

The European intensive system of animal production is nutrient deficient in itself. This deficit is covered through the import of, mainly, protein (nitrogen, N) in the form of soya and maize from the USA, among others. The nitrogen (N)-cost defined by Azzaroli Bleken and Bakken (1997) as the ratio between nitrogen fertiliser input (including animal manure) and the nitrogen present in the products is around 14 for dairy products and 21 for meat (while it is just 3 for wheat). It is clear that animal protein fixation has a relative low efficiency. Therefore, the input of proteic (nitrogenous) compounds into the animal feed is in excess. This nitrogen finally ends up in the animal excreta. The problem is posed: there is a continuous input of nitrogen which does not leave the system, the loop is open. Livestock farming influences the environment. This production system and its implications conform the reality and the problems to be solved.

When extensive animal farming was a general practice, there was an equilibrium between roughage production, meat and dairy products, and generated residues. Manure had a high value and it was rudimentarily composted on site and applied to the crops when necessary since it was relatively scarce. Through production intensification, extensive feed production was replaced by intensive cropping (with much larger nutrient inputs involved) while the popular know-how about residue management has not been replaced by a technological culture which values the large amount of residues produced.

The actual situation is quite paradoxical. One the one hand, slurry nitrogen elimination with energy consumption through the adequate combination of nitrification and denitrification is encouraged at local level. While on the other hand, Spain consumes some 4 million tons of mineral fertiliser per year. The energetic cost of producing this fertiliser is of 37 to 130 MJ (depending on the production method) per kg of N fixed from the atmosphere into the fertiliser, and of 14 MJ per kg of phosphorous (P). Moreover, there is concurrence in the organic wastes market between animal manure, organic residues from industry, the organic fraction of urban garbage, and sewage sludge.

The objectives of the case study, promoted by the Juncosa Farmers Association (JFA), were: to characterise the wastes produced by the livestock of Juncosa de les Garrigues, to establish the nutrient balance between crop requirements and the production of wastes by livestock, and the assessment of waste treatment technologies for the improvement of the manure characteristics so that they acquire an economic value which allows their export or sale.

Waste management planning

The above mentioned concurrence in the organic wastes market should drive the market to the application of high quality soil amendments through a global perspective, and through the necessary technological and control tools. An adequate global perspective needs the development of integrated management plans for organic residues. A plan must consider all production sectors and the concept of integrated management. Plans should be developed per territorial units, preferably per hydrographic basins. The final objective of a management plan is transforming the wastes into agronomic or energetic resources. A management plan for livestock wastes is a programme of actions leading to the adequacy of waste production to crop needs, in time and space.

Such a plan must necessarily consider actions leading to the following objectives:

1. Reduction of waste generation in two ways:

- flow reduction, which is interesting for liquid wastes such as pig slurry containing more than 90% water. A reduction in flow production rate saves money to the farmer and reduces transport and treatment costs
- reduction of limiting components such as nitrogen, phosphorous and heavy metals. Larger doses of wastes with a low concentration in limiting components can be applied than of heavily loaded wastes. This can be achieved modifying animal feed. Research is needed in this field

2. Establishment of a soil and crops application programme. This programme must define:

- the dose per application, number of applications, and total yearly dose that can be applied
- the moment of application according to crop needs, rainfall, and limiting temperature
- method of application (spraying, injection, ...)
- complementary good agricultural practice measures, such as minimum distances from the applied area to watercourses.

3. Assessment of the eventually necessary treatments.

A treatment modifies the waste characteristics to adequate them to the market as a quality product. This adequation could be done to:

- Equilibrate demand and offer in time

- Improve transport and application
- Improve its composition.

The concrete objectives of a treatment can be:

- Flow regulation (adequacy of waste production to demand, in time)
- Export out of the territorial unit
- Economically valorising the waste
- Complementing its composition to fit soil and crop requirements
- Extraction of valuable components of the waste
- Hygienise the waste.

The adopted action will depend on the territorial unit, its characteristics and its needs, the quality of the final product, the costs of its transformation and its market. In any case, the basic objective must be to increase the management capacity on the residue (Flotats et al., 1998). A treatment is a combination of unitary processes in order to achieve a given objective. A non exhaustive list of unitary processes that can be applied is:

- phase separation,
- flow homogenisation,
- nitrification,
- denitrification
- ammonia stripping
- absorption/generation of ammonium salts
- aerobic oxidation of organic matter
- composting (in fact, is a combination of other processes)
- thermal sterilisation
- anaerobic reduction of organic matter to methane (biogas)
- phosphorous chemical precipitation (apatite)
- precipitation/flocculation of other components
- precipitation of phosphorous and ammonium salts (struvite)
- biological phosphorous reduction (combination of anaerobic and aerobic processes)
- drying, pelleting, ...

Pollution (as mentioned in the introduction) is mainly a matter of placement of a resource/residue and of its amount. With this principle in mind, the definitive solution to livestock waste contamination would be the establishment of a general policy for a given territory. This policy should be based on the crops nutrient needs, on the different soil characteristics related to their nutrient carrying capacity, on the necessary distances between farms because of sanitary reasons, on the global animal carrying capacity of the territory, on the economic optimum of production, on the cost of transportation, on the localised need and adequacy for waste treatment plants, on water availability, on under and aboveground water quality, the generation of other residues, the pursuit of high quality production (including traceability) ... Unfortunately, such a policy is not easy to establish anywhere. In any case, three concepts must be taken into account: to know the territorial unit of study, to plan actions in the short and long terms, and to unite related productive sectors (crop and livestock farmers among others).

Characterisation of the area and of the farms of the JFA

Juncosa de les Garrigues is a municipality at the les Garrigues county in Lleida, Catalonia, NE Spain. The average pluviometry of the area is 526 mm. The probability that it be of 398 mm is 80%, while the probability of a rainfall of 692 mm is 20%. The soils have 15% $CaCO_3$. In general, their electrical conductivity (EC) is low, between 0.1 and 0.2 dS m^{-1} and the soil sodium content is also low.

There are 3,227 ha suitable for agricultural use. The 96.6% of this surface is occupied by olive trees and almond trees.

The JFA fattens an average of 9,357 calfs a year. Most of them are Hollstein. Most of the stables have a capacity ranging from 100 to 300 heads. Most of the stables are built around the village, in such a way that their geographical centre is the main square of the village. Fattening takes an average of 9.7 months. Calfs consume some 1.5 kg straw/head and day, some 15 to 16 L of water/head and day, and 5 to 5.5 kg feed/head and day. They produce about 5.8 kg manure/head and day (16,843 t manure per fattening for all the JFA or 20,319 t manure/year). Nowadays, some 4,000 t manure/year are exported from the municipality. The stables are cleaned every 10 to 15 days. The average manure storage capacity is of 4.3 months.

Most of the farms rent land to legalise the stable, even if manure is not applied on that land. The not exported manure is applied to the nearest agricultural land owned by the farmer, as close as possible to the farm. Far away land is rarely manured. Manure is not applied in a uniform manner in time nor in space to all the available surface, but 4 year rotations are established. This practice has negative repercussions for the most intensively manured soils (salinisation) and the underground waters, since nutrient applications are larger than nutrient extractions by the crops.

Characterisation of the manure

The average chemical characterisation of the manure is shown on Table 1.

The manure from Juncosa has a higher electrical conductivity than the optimum one for an organic soil amendment. If manure is not applied in a rational way (as deep fertiliser and according to crop needs) there could be salinity problems in the long term.

The nitric nitrogen content is somewhat higher than the values found in literature (Soliva, 1998). The use of phosphorous containing detergents and disinfectants leads to a large variability in the phosphorous (P) content of the manures. About 52% of the potassium (K) present in the manures is in exchangeable form, thus available to the crops. This value is above the ones usually found in literature (Dielh et al., 1985, Meeus-Verdinne et Destain, 1993, Navarro et al., 1995) and it is an indicative of the good quality of manure as a fertiliser.

Table 1. Average characteristics (n=12) of the manure from the JFA expressed on dry matter (d.m.) and fresh matter (f.m.). The coefficient of variation (CV) is indicated in percentage

Parameter (units)	**On d.m. (% CV)**		**On f.m. (% CV)**	
Dry matter (% w/w)	100		27.0	(15.7)
Volatile solids (% w/w)	82.7	(3.5)	22.3	(14.7)
PH			8.4	(2.7)
EC_{25} (dS m^{-1})	18.0	(7.0)		
COD (g O_2 g^{-1})	1.3	(3.5)	0.3	(14.7)
Total N (mg g^{-1})	30.2	(10.1)	8.2	(17.4)
Org-N (mg g^{-1})	23.5	(11.3)	6.4	(22.9)
NH_4^+-N (mg g^{-1})	4.7	(46.9)	1.3	(28.1)
NO_3^--N (mg g^{-1})	2.0	(51.6)	0.6	(55.6)
C/total-N			15.1	(8.7)
C/org-N			19.5	(12.2)
P (mg kg^{-1})	802.0	(176.3)	337.0	(111.8)
K (mg g^{-1})	25.8	(13.1)	7.0	(21.5)
Mg (mg g^{-1})	4.4	(27.2)	1.1	(19.3)
Ca (mg g^{-1})	25.4	(75.2)	4.8	(80.7)
Na (mg g^{-1})	6.9	(9.6)	1.8	(18.8)
Zn (mg kg^{-1})	6.2	(127.9)	1.4	146.4)
Cu (mg kg^{-1})	<1.0		<1.0	

Nutrient balance and general diagnosis

The nutrient balance shown on Table 2 is made considering the nutrient crop requirements in the municipality, and the generation of nutrients in the form of manure. The manure production was estimated by paying a visit to each stable and making an inquiry to each farmer of the JFA. The data relative to the amount of waste produced and its composition from the non members farms of the association (poultry, pigs and bovine) was estimated. Application is different from production since there occurs an average export of 4,000 t manure/year out of the municipality. Therefore, the effective livestock waste charge in the municipality is lower than the one considered on Table 2.

Table 2. Yearly nutrient balance at Juncosa de les Garrigues (1998)

Nutrient	Crop extractions (ton/year)	JFA production (ton/year)	Non member farms production (ton/year)	Extraction – production (ton/year)
N	288.2	166.6	89.1	32.5
P	48.1	4.2	50.6	-6.7
K	322.7	139.0	165.8	17.9

The only excedentary element is phosphorous mainly brought in by poultry manure. The soil characteristics of the area may tolerate a slight phosphorous surplus, though the export of poultry manure out of the municipality is preferable.

From the nutrient balance, and the characterisation of the studied area, one can conclude that the existing livestock waste load does not affect soil and water quality provided that manure application to the crops is done according to the good agricultural practice code (DOGC Núm. 2761-9.11.1998), synchronising crop needs and applications on all the available agricultural land of the municipality, and avoiding the existing practise of applying only on the closest land. Manure must be ripe (fermented and stabilised, that is, at least roughly composted) when applying it, because of hygienic reasons and in order to avoid leaching.

The fulfilment of all the above mentioned conditions requires an average (for all the members of the JFA) storage capacity equivalent to the manure production of 8 months. However, the actual average storage capacity is of 4.3 months. This existing storage capacity complies with the minimum required by the regulations but is not adapted to the fertiliser needs of the area under study. Therefore, it is necessary to either increase the storage capacity or to export manure out of the municipality.

If the second alternative is adopted, it would be advisable to jointly treat at least 50% of the manure produced in the municipality to sell it in the organic fertilisers market. The adopted treatment should increase the value of the manure in that market.

Assessment of treatment alternatives

Assessment of the anaerobic digestion technology for energy generation

With the objective of determinig if anaerobic digestion with methane (CH_4) production for its transformation into electrical and/or thermal energy is a feasible alternative for the JFA manure treatment, a batch mesophillic anaerobic digestion experiment was performed in the laboratory. Manure diluted with water at different rates (22% d.m., 16% d.m., 10% d.m., and 5% d.m.), was digested at 35ºC for up to 50 days in airtight 120 mL glass bottles. Four replications per treatment were digested. Methane production was followed at regular time intervals through all the incubation period. Headspace gas samples were analysed with a gas chromatograph. A different series of bottles was prepared for each sampling time since other parameters such as the eliminated COD, the volatile solids content, and the evolution of volatile fatty acids concentration (results not shown) were destructively quantified on the same days of gas sampling. A summary of the results is shown on Table 3.

Table 3. Average methane production and yield ratios obtained from the different dry matter initial concentrations in the anaerobic batch test (d.m.: dry matter, v.s.: volatile solids)

Parameter	**5% d.m.**	**10% d.m.**	**16% d.m.**	**22% d.m.**
CH_4 (mL)	188.66	129.71	63.78	44.03
eliminated COD (%)	54	15	17	10
Eliminated v.s. (%)	47	14	9	5
mL CH_4/ g initial v.s.	161.30	58.13	18.19	9.17
mL CH_4/g initial COD	92.70	33.11	10.33	5.22
ml CH_4/g eliminated v.s.	348.38	418.10	197.72	179.12
mL CH_4/g eliminated COD	171.93	219.05	60.40	50.54
Biodegradability index	54	15	17	10

On the basis of the results obtained a numeric simulation was done to assess the feasibility of a continuous anaerobic digestion plant. It was concluded that some 1,210 L water/ton of manure would be necessary to reach the optimum total solid concentration, leading to an electrical energy production of 3,060 MW·h/year and a gross income (from the sale of this energy) of no more than 45 million pta/year.

There would be a generation of 44,200 m^3/year of a very diluted (about 7% d.m.) mixture of manure with water as a by-product containig some highly mineralised organic matter. This by-product should be treated by some means before being applied onto the agricultural land. To favour its export out of the municipality it would be necessary to separate or evaporate its water making the plant more expensive and more complicated. If the choice of separating its water was adopted, this water should be treated before discharge. The plant could be paid-back only after 15 years. Therefore, the economic risk associated with it is high.

Therefore, from the results obtained from the anaerobic digestion experiment and from the simulations made with them, it can be concluded that calf manure with straw bed is not suitable for anaerobic digestion, though the final energy production is remarkable. The reason for this unsuitability are: the unavailability of the water (or other appropriate liquid residues) required, the large investment needed, the difficulty in managing the fermented by-product and its poor agronomic value relative to aerobic compost.

Assessment of composting technology

Which the objective of determining if composting is an adequate process to improve the organic fertiliser quality of manure and its management, an experiment was performed, composting 20 tons of manure at the county comercial composting plant of Botarell (Baix Camp, Catalonia, Spain).

Through composting (3 months, July to September), the volume of the windrow decreased by 46%. The water content decreased through the process in such a way that the initial dry matter content was of 43% while the final one was of 62%. The density of the material decreased from 550 to 400 kg/m^3. If all the manure produced by the JFA was composted, the 20,319 ton fresh manure produced per year in the municipality would be reduced to 7,979 ton of compost/year with the subsequent decrease in transportation costs.

The average main characteristics of the produced compost are summarised in Table 4. The obtained product is of an excellent quality.

Table 4. Average characteristics of the compost produced from manure and legal requirements for compost according to Spanish regulations

Parameter (units)	Juncosa compost	Regulation requirements BOE nº131 (2/6/98)
Dry matter (%)	61	> 60
Organic matter (% on d.m.)	72.5	> 25
COD (g O_2 g^{-1} on d.m.)	0.53	
Org-N (mg g^{-1} on d.m.)	26.3	> 10
P (mg g^{-1} on d.m.)	15	
K (mg g^{-1} on d.m.)	34.4	
Zn (mg kg^{-1} on f.m.)	15.7	< 1100
Cu (mg kg^{-1} on f.m.)	60	< 450
CE_{25} (dS m^{-1})	14.7	

The potassium content is higher than expected. This is probably due to its high concentration in the pit water used for moistening the composting windrow at Botarell facilities. It is expected that when composting at Juncosa the compost potassium content would be around 24 mg/g on d.m. basis.

Because of its characteristics, this compost would be appreciated for vineyard and orange tree cropping, and ecological olive tree cropping. The market price of compost is very variable. However, one can estimate that, if all the manure produced in the municipality was composted, the gross income (due to the sale of the product) would be of about 40 million pta. When substracting the cost of the needed water (46 L/ton of produced compost), personnel, transportation and paying-back of machinery and civil works, there is still a reasonable benefit margin. It would be advisable that the JFA contacted a residue manager with a remarkable knowledge of the compost market.

Conclusions

The general conclusion of the present case study is that there does not yet exist a problem in Juncosa due to the generation of manure by the JFA. There is no such production that could pose a risk for soil and water quality. However, to avoid the appearance of such a problem manure should always be applied ripe and on all the available surface coinciding in time with crop needs.

If all the manure actually produced was to be used within the municipality, it is necessary to enlarge the storage capacity. On the other hand, if the external valorisation of the manure in the organic fertilisers market was desired the most suitable process, of the ones assessed, is composting. Composting leads to a product of a good fertiliser quality valued in the market and it needs little investment. The process of anaerobic digestion for energy production is not advisable at this site.

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