ON-FARM FERTILIZER PRODUCTION OPTIMIZATION

Billi L.[1], Bonoli A.[2], Dall'Ara A.[3], Massi P.[4], Poglayen G.[5]
[1]Arpa Emilia-Romagna, Via Alberoni 13-17, 48100 Ravenna, Italy, +39 0544 210611, lbilli@arpaemr.it
[2]Bologna University, DICAM, via Terracini 28, Bologna, Italy, +390512090234, alessandra.bonoli@unibo.it
[3]ENEA, Via Ravegnana, 186,48010 Faenza, Italy, +39 0546 678550, alice.dallara@enea.it
IZS, Via Marchini 1, 47100 Forlì, Italy, paola.massi@iszler.it
Bologna University, D Public Health & Animal Pathology, Via Tolara Sopra 50, 40064 Ozzano, Italy, giovanni.poglayen@unibo.it

1 INTRODUCTION

Currently in Italy, poultry manure (PM) is spread to agricultural soils and incorporated pre-sowing according to nitrate directive CEE/91/676 and manure Agronomic Use Plan (D.Lgs. 152/99). The nitrogen (essential element for the development and growth of plants) contained in ureic form comes to mineralization in a few weeks: it is readily available but not usable by plants, unless they are not characterized by a short life cycle.

For caged laying hen manure (LHM), carbon and nutrient content are function of diet and manure management system; furthermore carbon and nitrogen are affected also by maturation processes, which often reduce them via CO_2 and ammonia volatilization respectively, particularly in the case of wet manure.

The project is part of a general project for LHM sanitation through the application of new biological technologies (bio-treatment) (Dall'Ara et al., 2010). The goal of the work is to check the effect on optimize nutrient and organic content by means of a biotreatment which overcomes the management of manure (livestock outputs) as waste by means of sanitation process to obtain quality marketable fertilizer, that improves the soil structure, enhances its fertility and prevents desertification. From a nutrient point of view, the purpose was to minimize nitrogen and carbon losses.

2 MATERIALS AND METHODS

2.1 Materials

Tests were performed on an Italian intensive farm. LHM was collected from a commercial poultry unit with vertical tiered cages and Manure Drying System (MDS). Manure was removed from housing after 24-36 hours by means of manure conveyor belts and dried in a tunnel outside the housing (MDS) in the subsequent 72 hours. MDS, classified as BAT (Best Available Technique) according to BREF (EC, 2003), allows drying up to 85% DM.

For bio-treatment an innovative Italian technology was used, based on a European patent pending process (AMEK, CTI, 2002). It describes a natural enzymatic mixture named PAV (Vegetable Active Principles), prepared from selected plants, picked up in their balsamic period, that is to say at the time of maximum vegetative development . Raw materials are plants belonging to the following families: Cucurbits, Grass, Labiates, Umbellifers and Rue, able to develop flavours and scents and to give vitamins (especially A, C, E). PAV are prepared by comminuting such raw materials to under the size of a grain of rice and then mixing them with natural liquids. Then they are poured onto the heap/substrate to treat. In doses ranging from 0,1 to 2 kg/m^3 of treated substrate, in function of pile dimension. PAV have been developed in order to speed up biooxidation processes, to reduce biomasses turning and to maintain N in slow release form (AMEK, CTI, 2002).

2.2 Experimental design

Bio-treatment tests were performed directly in a big bag (1 m^3), the packaging for final trading, and in a pile set in a barn with impermeable floor, used for manure storage, during the period from October 2008 to April 2009. Treatment consisted in adding PAV to dried manure inside big-bags, during filling, at a dose of 1 kg per big bag (≥ 1m^3). Big-bags are the bioreactor where manure matures by static batch process; at the end they are closed and are ready for marketing. The method of fertilizer production is shown in Figure 1. A pile was formed in 4 weeks, with a dimension of about 480 m^3, and a quantity of 90 kg of PAV added along/ its formation.

The experimental planning was developed using Design of Experiment (DOE) in the case of big bags. This is a methodology for statistical design of an experiment used to describe a complex biological process. DOE reduces the number of experiments to be performed in complex systems characterized by many variables that affect the process.

Screening design was based on previous tests performed at the same intensive farm, which had indicated 2 vital factors: LHM dry matter (DM%) and maturation time (t). Consequently a fully factorial 2^2 plan was adopted where the variables were initial LHM dry matter (63%, 72%, 81%) and maturation time (38, 81, 123 days) to assess their effects and their interaction. The fully factorial with central point design (4 replicates of central point) was adopted (Montgomery, 2005), as shown in Figure 2. A comparative pile treatment was performed. Also LHM characterization at t=0 (just outside MDS) was executed.

2.3 Sampling

Sampling procedure was in agreement with regulation EC 1774/2002 (annex VIII, chapter III), which requires 5 sampling points for each material. Therefore, for each big bag, 5 subsamples of about 0.2 kg were collected, united and mixed to form a composite sample for chemical analysis. Every big bag was completely opened for sampling; (i.e. one big bag was prepared for each sampling).

2.4 Analysis

Sub-samples of “wet manure” were taken and analysed for dry matter (DM) content, pH, nitrogen as Total Kjeldahl Nitrogen (organic nitrogen and ammonia). Dry matter was ground and analysed for total phosphorus. Volatile solids (VS) were determined as loss on ignition ashing DM in an oven at 550°C for 2 hours and determining the weight loss. Additional “wet manure” sub-samples were taken and oven dried at 60°C for more than 12 hours (until constant weight) and then ground with a micro-mill under 0.2 mm and analysed for organic carbon (TOC) by total organic carbon (TOC) analyzer RC412 (LECO, Milano, Italy). All analyses were performed in accordance with officially recognized methods for compost analysis (ANPA, 2001); total phosphorus analysis was performed according to officially recognized methods for fertilizers (Trinchera et al., 2006). All analyses were repeated at least once to check the homogeneity of sub-samples and analysis methods.

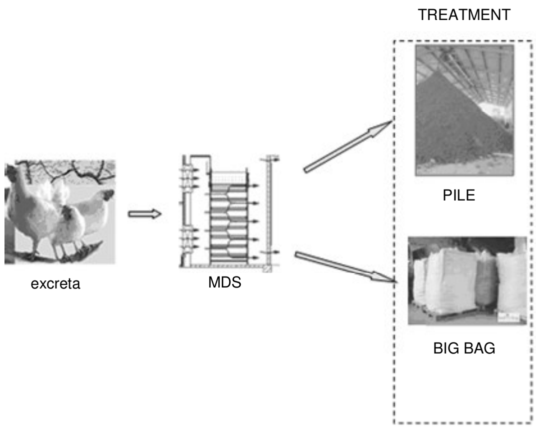

FIGURE 1 **Scheme of experimental tests**

3 RESULTS AND DISCUSSION

Response parameters were TOC and TKN, where TOC is expressed as % DM, while TKN is expressed as % on wet basis according to Italian regulation; also DM, VS, P_2O_5, , pH and electrical conductivity were measured. Mass loss was checked. The results of TOC determination for big bags are shown in Table 1. The first evidence is LHM homogeneity just after MDS (all figures ≥ 30 % DM). Furthermore data indicate a substantial maintenance of TOC concentration over the treatment period, that is to say that there was little effects of maturation time and water content on TOC. The results of TKN content for big bags (table 1), show variability in initial samples, due to variability of nitrogen concentration in poultry manure (produced in that protocol); variability seems to reduce towards final phase (123 days), just as treatment could standardize final products; further investigations are needed. Carbon and TKN trends in pile are reported in Table 2; there are no differences from the observations for big bags.

Analysis of variance (ANOVA) applied to big bags shows that the effects of selected independent variables (DM%, maturation time) and their interactions are not relevant to describe response parameter (TOC, TKN); there are not statistically significant differences for TOC and TKN within the ranges of considered independent variables.

About humidity, there is different behaviour for LHM in big bag and in pile: water content does not undergo substantial changes in big bags during treatment; on the other hand there is a trend towards drying in pile. This can be partially explained by temperature evolution during the treatment: spot measures have shown that pile reaches thermophilic conditions, with $T_{average}$ of 60,9 (± 7,5) °C during its formation, it maintains $T_{average}$ 50,1 (±12,7) °C at the end of formation; in the meanwhile, in big bag, temperature doesn't reach values typical of composting processes.

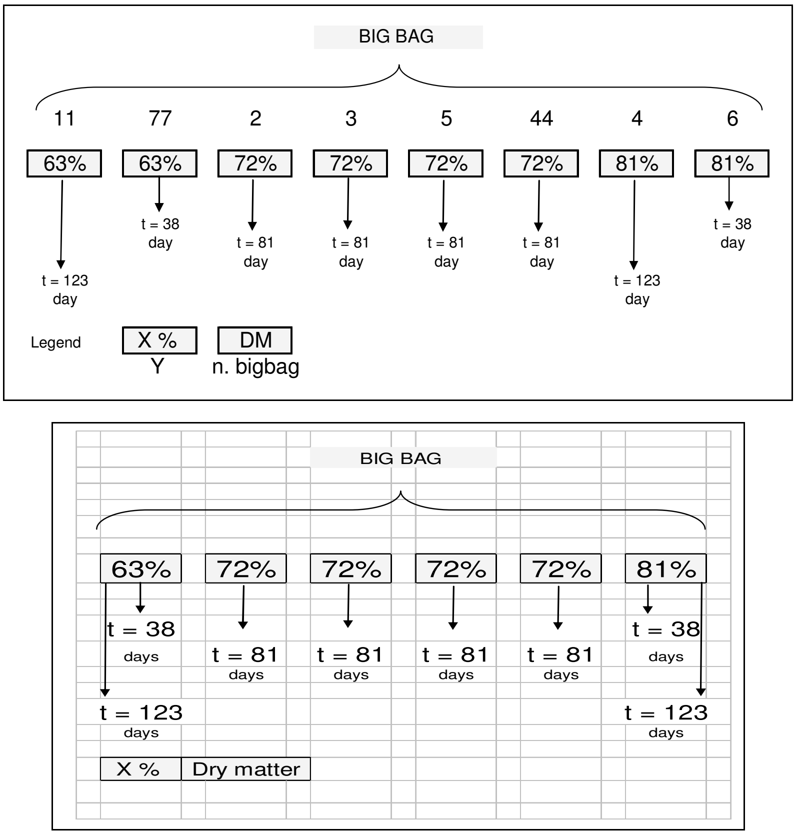

FIGURE 2 **Experimental design: : fully factorial with central point design (4 replicates of central point)**

TABLE 1 **Results of Carbon (TOC) and Nitrogen (TKN) determination**

Big bag n.	**DM** (% ± SD) **t = 0**	**TOC** (%DM) **t = 0**	**TKN** (%) **t = 0**	**DM** (% ± SD) **t=Final**	**TOC** (% DM) **t =Final**	**TKN** (%) **t=Final**	**Final time**
11	63.2 ± 1.6	30.3	1.91	73.6 ± 0.6	32.3	3.12	t = 123 d
77	"	33.3	2.64	"	33.4	2.48	t = 38 d
2	71.7± 5.1	33.5	2.91	75.2 ± 7.1	35.1	3.30	t = 81 d
3	"	33.1	2.91	"	30.8	2.94	t = 81 d
44	"	33.3	2.64	"	32.1	4.21	t = 81 d
5	"	32.2	3.17	"	30.0	3.01	t = 81 d
4	81.1 ± 4.2	33.1	3.42	75.2 ± 6.8	31.8	3.04	t = 123 d
6	"	30.0	2.20	"	28.8	2.32	t = 38 d
Mean value (± SD)		32.4 ± 1.4	2.72 ± 0.46		31.8 ± 2.0	3.02 ± 0.56	

TABLE 2 **Results of Carbon (TOC) determination together with Italian regulations requirements for "commercial amendment, manure"**

Big bag n.	DM (% ± SD) t = 0	TOC (%DM) t = 0	DM (% ± SD) t=Final	TOC (% DM) t =Final	Δ TOC (%)	Final time	Italian Law requirements
11	63.2 ± 1.6	30.3	73.6 ± 0.6	32.3	2.0	t = 123 d	DM < 30%
			"				TOC > 30%
77	"	33.3		33.4	0.1	t = 38 d	DM
2	71.7± 5.1	33.5	75.2 ± 7.1	35.1	1.6	t = 81 d	
3	"	33.1	"	30.8	-2.3	t = 81 d	
44	"	33.3	"	32.1	-1.2	t = 81 d	
5	"	32.2	"	30.0	-2.2	t = 81 d	
4	81.1 ± 4.2	33.1	75.2 ± 6.8	31.8	-1.3	t = 123 d	
6	"	30.0	"	28.8	-1.2	t = 38 d	
Mean value (± SD)		32.4 ± 1.4		31.8 ± 2.0	-0.6 ± 1.6		

TABLE 3 **Results of Nitrogen (TKN) determination together with Italian regulations requirements for "commercial organic fertilizer NP, Dried Poultry Manure" ,**

Big bag n.	DM (% ± SD) t = 0	TKN (%) t = 0	DM (% ± SD) t=Final	TKN (%) t=Final	Δ TKN (% DM)	Final time	Italian Law requirements
11	63.2 ± 1.6	1.91	73.6 ± 0.6	3.12	1,21	t = 123 d	TKN > 2%
77	"	2.64	"	2.48	-0,16	t = 38 d	P_2O_5 > 2%
			75.2 ± 7.1		0,39		TKN +P_2O_5 >
2	71.7± 5.1	2.91		3.30		t = 81 d	5%
3	"	2.91	"	2.94	0.03	t = 81 d	
44	"	2.64	"	4.21	1.57	t = 81 d	
5	"	3.17	"	3.01	-0.16	t = 81 d	
4	81.1 ± 4.2	3.42	75.2 ± 6.8	3.04	-0.38	t = 123 d	
6	"	2.20	"	2.32	0,12	t = 38 d	
Mean value (± SD)		2.72 ± 0.46		3.02 ± 0.56	0.3 ± 0.7		

TABLE 4 **Results of Carbon (TOC) and Nitrogen (TKN) determination for pile**

Parameters	**t = 0**	**t = 38 d**	**t = 81 d**	**t = 123 d**
DM (%)	53.3	66.4	70.0	79.1
TOC (% DM)	31.3	29.5	29.5	29.9
TKN (%)	2.66	3.14	3.58	3.27

Italian regulations for commercial fertilizers (D.Lgs. 75/2010) lists organic fertilizers such as dried poultry manure; the requirements are reported in Table 3. Furthermore it defines also "organic amendment, manure" asking DM < 30% and TOC > 30% DM.

TABLE 5 **Requirements for organic fertilizer NP dried poultry manure**

Parameters	**Minimum value**
Total Nitrogen as **N** (%)	2
Total Phosphorus as P_2O_5 (%)	2
N + P_2O_5 (%)	5

4 CONCLUSIONS

Chemical analysis have shown that TOC and TKN contents for final product satisfy requirements of Italian regulations for commercial fertilizers (D.Lgs. 217/06); also measured total phosphorus ($P_2O_5 \geq 2,5$ %) is in agreement with law. Therefore, final product can be classified as "NP organic fertilizer", dried poultry manure.

By means of a parallel test, time needed for sanitation, according to Regulation CE/208/2006, was assessed in 123 days; during this time, carbon and nitrogen contents did not undergo substantial changes; therefore sanitation bioprocess does not reduce nitrogen and carbon content. Indeed, the final fertilizer in big bag is characterized by high carbon content, enough for being classified as amendment.

Also statistical analysis for TOC and TKN show that "big bag system" is not affected either by initial water content or maturation time in considered ranges. However, these preliminary considerations need further investigations

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