Report on soil carbon and nitrogen behaviour

(WPT1_Activity 3_Deliverable 3.2)

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List of abbreviations

AD: Anaerobic digestion

AN: Ammonium nitrate

ANSES: the French Agency for Food, Environmental and Occupational Health and Safety

AS: Ammonium sulphate

AW: Ammonia water

B1: Blend 1

B2: Blend 2

CaE: Concentrate after evaporation

CAN: Calcium ammonium nitrate

CO_2: Carbon dioxide

DM: Dry matter

EC: Electrical conductivity

EOM: Exogenous Organic Matter

H_2SO_4: Sulphuric acid

IROC: Indicator of Remaining Organic Carbon

JRC: Joint research center

KCl: Potassium chloride

LF: Liquid fraction

MFSC : Matières Fertilisantes et Supports de Culture = fertilising material and crop support

$N_{rel,net}$: Net N release

$N_{min,net}$: Net N mineralisation

NH_4^+-N: Ammonium-N

NFU: French normalisation

NO_3^--N: Nitrate-N

OC: Organic carbon

OM: Organic matter

PU: Pig urine

PVC: Polyvinyl chloride

RDFs: Recycling-derived fertilisers

SF: Solid Fraction

SOC: Soil Organic Carbon

WFPS: Water-filled pore space

1. Introduction

A balanced supply of important plant nutrients will result in good crop yield and quality. Balanced nutrition is also an essential element in sustainable crop and soil management. Nitrogen (N) is one of the most essential macro-nutrients and its deficiency can limit crop growth. However, an excess of N can result in poor N use efficiency and possible losses to the environment.

N mineralisation is a biological process which contributes to the plant-availability of N, thereby promoting healthy growth of plants. It involves the microbial conversion of organic N to ammonia (NH_3) that stabilises in most non-alkaline soils as ammonium ions (NH_4^+). Studying N mineralisation and release provides a better understanding in the study of N availability from recycling-derived fertilisers (RDFs) and in efficient predictions of N fertilisation. Similarly, predicting how much organic carbon (OC) will mineralise in a growing season will help in understanding the agricultural value of certain organic RDFs like composts.

In keeping with the concept of Circular Economy, it is necessary to evaluate the potential of RDFs to replace the synthetic mineral fertilisers. With this aim in sight, two partners of the ReNu2Farm project (UGhent and Arvalis) conducted soil incubation studies to assess the N mineralisation and release potential of ammonium sulfate, ammonium nitrate, ammonia water, pig urine, concentrate after evaporation and three different types of compost. Even though the first three RDFs are known to contain total N in mineral form, they are still not legally accepted as subsitutes for synthetic N fertilisers. Therefore, this study allows to gain insights into the behaviour of these recovered ammonium solutions as compared to their conventional counterparts, along with the behaviour of pig urine and concentrate after evaporation (Chapter 2). As compost is also known to contain carbon (C) along with N, Arvalis performed both N and C incubation tests on compost that is derived from animal manure (Chapter 3).

Soil incubation experiments to study the N and C dynamics of added RDFs into the soil will act towards providing better insights into the performance of these products, thus helping in valorising them as fertilising products in the European market.

2. Nitrogen incubation experiment by UGhent

2.1 Introduction

In the ReNu2Farm project, 24 RDFs were characterised for their physico-chemical parameters. Out of the 24 products, five RDFs (ammonium nitrate, ammonium sulphate, ammonia water, pig urine, concentrate after evaporation) and their two tailor-made blends were tested by UGhent in controlled laboratory experiments to determine their efficiency as a N fertiliser and its potential to replace the synthetic mineral N fertilisers. As part of the project outputs, 10 tailor-made blends from the RDFs were theorised (see WPT1_D3.1 *Report on mineral nutrient composition of analysed recycling-derived fertilisers*) and two of them were tested in the laboratory experiments. This report expounds on the soil incubation experiment conducted in absence of plants to assess the N mineralisation and N release potential of the RDFs in comparison to the synthetic N mineral fertiliser calcium ammonium nitrate (CAN). Moreover, the nutrient use efficiency of the tested RDFs in the incubation experiment was also assessed in pot cultivation of lettuce. These results, however, are reported in the ReNu2Farm report of WPT2_D2.2 *Report on nutrient use efficiency determination under controlled conditions*.

2.2 Materials and methods

2.2.1 Collection and analyses of soil

The soil used for the incubation experiment was collected from the surface layer (0 - 30 cm) of an arable field in Wingene, Belgium. It is the field where the Flemish field trials for ReNu2Farm are conducted by Inagro in collaboration with UGhent. This part of Flanders has a predominantly sandy soil and according to the Belgian soil map, the field's soil profile is characterised as a Z.c.h. soil type (soil with sandy texture and a moderately poor drainage class with signs of rust deeper than 60 cm and a postpodzol B-horizon) (Van Ranst and Sys, 2000). The field was part of a mixed cattle-extensive vegetable farm and the crops mainly grown on this farm in 2017 and 2018 were *Zea mays* (maize) and *Solanum tuberosum* (early potatoes) respectively. The organic fertiliser mainly used was farmyard manure (with straw at a low N and P content). Italian ryegrass was the catch crop grown mostly in this field.

The soil was collected on 21st March, 2019, before the fertiliser application and sowing of the field for the 2019 trial with maize. The soil was air-dried in the greenhouse at UGhent, sieved using 2mm sieves, and mixed thoroughly before analyses. The air-dried soil was stored in the greenhouse in plastic bags until start of the experiment. A sub-sample of the soil was taken and the soil organic carbon (SOC), pH using potassium chloride (pH-KCl), electrical conductivity (EC), and total N analyses were measured. SOC was measured in two setps: first the soil organic matter (SOM) was measured using a muffle furnace (Nabertherm, Germany) for 4 hours at 550°C, and secondly SOC was obtained by dividing the calculated SOM by a factor of 2 (Sleutel et al., 2007). pH-KCl determined the soil potential acidity and it was measured using a pH meter (Orion Star A211, Thermo Fisher Scientific, USA) by adding 25 mL of 1M KCl to 10 g of air-dried soil and letting it equilibrate for 10 minutes (Ranst et al., 1999). For EC analysis, water extracts of 10 g of air-dried soil were prepared using de-mineralised water (after shaking for 60 minutes) and these extracts were filtered using a Whatman filter paper (pore size 125mm). An EC meter (WTW Tetra Con 96, Xylem Analytics, Germany) was used to determine the conductivity of the extracts. Total N was determined using the Kjeldahl digestion (FOSS Kjeltec™ 8000, Denmark) and total C by the CN analyser (Primacs100, Skalar, the Netherlands). Ammonium N (NH_4^+-N) (ISO 11732:1997) and nitrate N (NO_3^--N) (ISO 13395:1996) were extracted in 1M KCl by mixing 10 g soil in 50 mL KCl. These extracts were prepared after being shaken for 30 minutes on a rotary shaker and the supernatant filtered out using a Whatman filter paper of pore size 125 mm. It was then analysed using a continuous flow auto-analyser (Chemlab System 4, Skalar, the Netherlands). The characterisation results of the soil are presented in Table 2-1.

Table 2-1. Soil characterisation performed on air-dried soil.

Soil type	pH-KCl	EC (µS/cm)	OM (%)	OC (%)	Total N (g/kg)	NH_4^+-N (mg/kg)	NO_3^--N (mg/kg)
Sandy	5.8	55	2.6	1.3	1.1	18	67

Organic matter: OM; organic carbon: OC; electrical conductivity: EC

2.2.2 Collection and analyses of RDFs

The RDFs tested in this experiment were : i) ammonium nitrate (AN), ii) ammonium sulphate (AS), iii) pig urine (PU), iv) ammonia water (AW), v) concentrate after evaporation (CaE), vi) blend 1 (AN + CaE) (B1) and vii) blend 2 (AW + CaE) (B2). The blending of RDFs is detailed in chapter 4 of the ReNu2Farm report of WP1_D.3.1 *Report on mineral nutrient composition of analysed recycling-derived fertilisers.* The treatments with the two tailor-made blends were tested by addition of individual RDF forming the blend (1:1) into the soil, rather than actual mixing of the two RDFs. Hence, the tubes with soil containing AN + CaE were considered as B1 and ones containing AW + CaE were considered as B2. Reference fertiliser used was CAN. The experimental design also included a treatment with unamended soil (control). All tested RDFs were obtained from biomass processors based in

Belgium. The AN tested was obtained from a stripping/scrubbing system used to up-concentrate the liquid fraction (LF) of digestate obtained after anaerobic digestion (AD) of animal manure. The AS, on the other hand, was obtained by scrubbing the air of pig stables using sulphuric acid (H_2SO_4) as the scrubbing agent. A source-based manure separation system located in one of the pig farms in Flanders provided the PU. In this manure separation system, the urine is collected in a shallow cellar constructed beneath a slatted floor where solid faeces is separated form the liquid urine. Both the products, AW and CaE, result from evaporation of LF of digestate in an AD plant that processes various types of organic waste. The AW is the condensate after evaporation, whereas, the CaE is the residual concentrate rich in nutrients. This AD plant adds AW to the CaE at the end to market their CaE as a N fertiliser. Hence, CaE is observed to have a higher pH value and mineral N content. All RDFs were collected in polythylene sampling bottles of 2L and stored at 4°C before characterisation (Table 2-2).

Table 2-2. Characterisation of tested RDFs on fresh matter basis. Organic matter (OM) is presented as a percentage of dry matter.

Parameters	AN	AS	PU	AW	CaE
pH-KCl	5.7	6.1	8.7	11	9.8
EC (mS/cm)	303	165	48	312	15
DM (%)	23	25	2.2	n.d.	13
OM (% of DM)	n.a.	n.a.	n.a.	n.a.	62
OC (g/kg)	n.a.	n.a.	2.8	n.a.	31
Total N (g/kg)	82	39	6.1	155	4.6
NH_4^+-N (g/kg)	48	39	5.1	155	4.4
NO_3^--N (g/kg)	34	<0.002	<0.002	<0.002	<0.002
Organic N (g/kg)	n.a.	n.a.	1	n.a.	0.2
N_{min}/N_{total}	1	1	0.84	1	0.96
C/N_{total}	n.a.	n.a.	0.45	n.a.	6.7
$C/N_{organic}$	n.a.	n.a.	2.8	n.a.	155
$N_{organic}/N_{total}$	n.a.	n.a.	0.16	n.a.	0.04

n.a. : not applicable; n.d. : not determined
AN : ammonium nitrate; AS : ammonium sulphate; PU : pig urine; AW : ammonia water; CaE : concentrate after evaporation; EC : electrical conductivity; DM : dry matter; OM : organic matter; OC ; organic C; NH_4^+-N : ammonium-N; NO_3^--N : nitrate-N.

Determination of dry matter (DM) content of RDFs was done by drying them at 105°C to a constant weight for 48 hours, and calculating the DM as a percentage of its wet weight. OM was analysed by incineration of the dried solids at 550°C in the muffle furnace (Nabertherm, Germany) for 4 hours and subsequent loss of mass on ignition was considered as the result. Total and inorganic C were analysed using a CN analyser (Primacs100, Skalar, the Netherlands) and OC was calculated after deducting the inorganic C from the total C. pH-KCl and EC were both determined on fresh samples using a pH meter (Orion Star A211, Thermo Fisher Scientific, USA), and an EC meter (WTW Tetra Con 96, Xylem Analytics, Germany) respectively. Total N was determined by Kjeldahl digestion of samples and NH_4^+-N and NO_3^--N were determined by analysing extracts prepared in KCl using a continuous flow auto-analyser (Chemlab System 4, Skalar, the Netherlands). Organic N was calculated as the difference between total and mineral N (NH_4^+-N and NO_3^--N).

2.2.3 N incubation experimental set-up

On 31st July, 2019, the air-dried and sieved soil was pre-incubated at 35 % water-filled pore space (WFPS). This pre-incubated soil was placed in the dark at 21°C for one week after covering it with a pin-holed parafilm to prevent loss of moisture by evaporation. On 7th August, 2019, the experiment commenced. All the products to be tested were mixed with 259 g of pre-incubated soil at a rate of 200 kg N ha^{-1} which was the same dose of N applied to soil in the pot cultivation of lettuce. This N dosage was recommended for lettuce cultivation by Inagro (personal communication). The application rates of tested products are presented in Table 2-3.

Table 2-3. Application rates of treatments in tonnes ha^{-1} tested in the 120-day incubation experiment.

Treatment	tonnes ha^{-1}	total N (kg ha^{-1})	OC (kg ha^{-1})
CAN	0.67	200	0
AN	2.4	200	0
AS	5.2	200	0
PU	33	200	92
AW	1.3	200	0
CaE	43	200	1333
B1*	22 (CaE) + 1.2 (AN)	200	682
B2**	22 (CaE) + 0.65 (AW)	200	682

AN : ammonium nitrate; AS : ammonium sulphate; PU : pig urine; AW : ammonia water; CaE : concentrate after evaporation; B1 : blend 1; B2 ; blend 2; OC ; organic C.
*For B1: 22 tonnes ha^{-1} of CaE and 1.2 tonnes ha^{-1} AN
**For B2 : 22 tonnes ha^{-1} CaE and 0.65 tonnes ha^{-1} AW

For each treatment with an amendment, a homogenised mixture of soil and product was placed in PVC tubes of 18 cm length and 4.6 cm diameter. For the unamended control, plain soil was placed in the polyvinyl chloride (PVC) tubes. The soil in the tube was brought to a bulk density of 1.4 g cm^{-3} by compacting it using a wooden cylindrical block to a height of 10 cm. The moisture content in the soil was adjusted to 50 % WFPS and the tubes were covered with a pin-holed gas-permeable parafilm to avoid loss of moisture by evaporation, simultaneously, allowing air transfer. In total, 162 tubes (9 treatments x 3 replicates x 6 sampling moments) were randomised for their treatments and incubated in the dark at an average temperature of 21°C for a total experimental duration of 120 days. Figure 2-1 shows the set-up of the soil incubation experiment.

The moisture content was monitored every fortnight by weighing the tubes, and adjusted to 50% WFPS, for tubes where loss was observed. Three replicates of each treatment were sampled on days 20, 40, 61, 82, 100 and 120. The soil from the intact tubes was removed, mixed thoroughly, and 10 g from this mixture was taken to prepare KCl extracts to be analysed for NH_4^+-N and NO_3^--N (described in section 2.2.1). The mineral N in unfertilised control at day zero was determined again to include the effects of drying and re-wetting of soil.

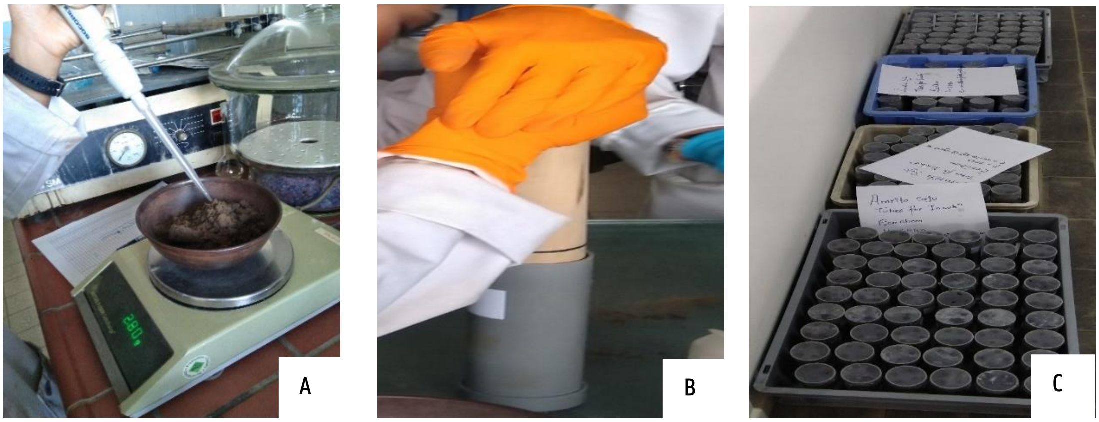


Figure 2-1. Set-up of the 120-day soil incubation experiment. (A) : Addition of fertiliser to soil; (B) : Compacting the soil mixed with fertilisers in the PVC tubes to obtain a bulk density of 1.4 g cm^{-3}; (C) Tubes covered with pin-holed gas-permeable parafilm, randomised and placed in trays to be incubated in the dark.

2.2.4 Data analysis

Two important parameters were calculated at the end of the experiment :

- Net N release ($N_{rel,net}$) presents the difference between the mineral N measured in the amended soil, i.e. soil treated with fertiliser, from the mineral N measured in the unamended soil, i.e. the control. $N_{rel,net}$ is calculated by the formula (De Neve and Hofman, 1996) :

$$N_{rel,net}\ (\%) = \frac{([NO_3^- - N, treatment - NO_3^- - N, control]) + [NH_4^+ - N, treatment - NH_4^+ - N, control}{N total\ applied} \times 100 \qquad \text{(Eq. 1)}$$

At t = 0, the $N_{rel,net}$ (%) equals the product $N_{mineral}/N_{total}$ ratio x 100.

- Net N mineralisation ($N_{min,net}$) gives the N mineralised from the organic fraction of the product (expressed as a percentage of the total N in the product) and is calculated by deducting the amount of mineral N present in the product at time zero (t = 0) from the amount of mineral N at time t as (Sigurnjak et al., 2017):

$$N_{min,net}\ (t; \%\ total\ N) = (N_{rel,net}\ (t) - N_{rel,net}\ (t=0)) \qquad \text{(Eq. 2)}$$

A positive $N_{min,net}$ value indicates net N mineralisation, and a negative $N_{min,net}$ indicates net N immobilisation.

2.3 Results

2.3.1 Mineral N evolution in the soil

At the start of the experiment, i.e. t = 0, all the RDFs supplied significant amount of mineral N in the form of NH_4^+-N to the soil as shown in Figure 2-2. During the initial stages of the incubation (on day 20), the unamended soil showed higher NH_4^+-N (4.6 mg NH_4^+-N kg^{-1}) compared to the all amended treatments (1.4 - 3.9 mg NH_4^+-N kg^{-1}), except CaE (5.5 mg NH_4^+-N kg^{-1}), indicating a stimulation of nitrification by addition of the RDFs, or a faster mineralisation of the soil organic N in the unamended soil.

The nitrification of NH_4^+-N via the added products was completed as was observed by the levels of negligible amounts of NH_4^+-N, and a stark increase in the levels of NO_3^--N. The NO_3^--N is observed to increase throughout the duration of the experiment, with the nitrification pattern closely following the ammonification pattern, i.e. any NH_4^+-N produced was quickly converted to NO_3^--N.

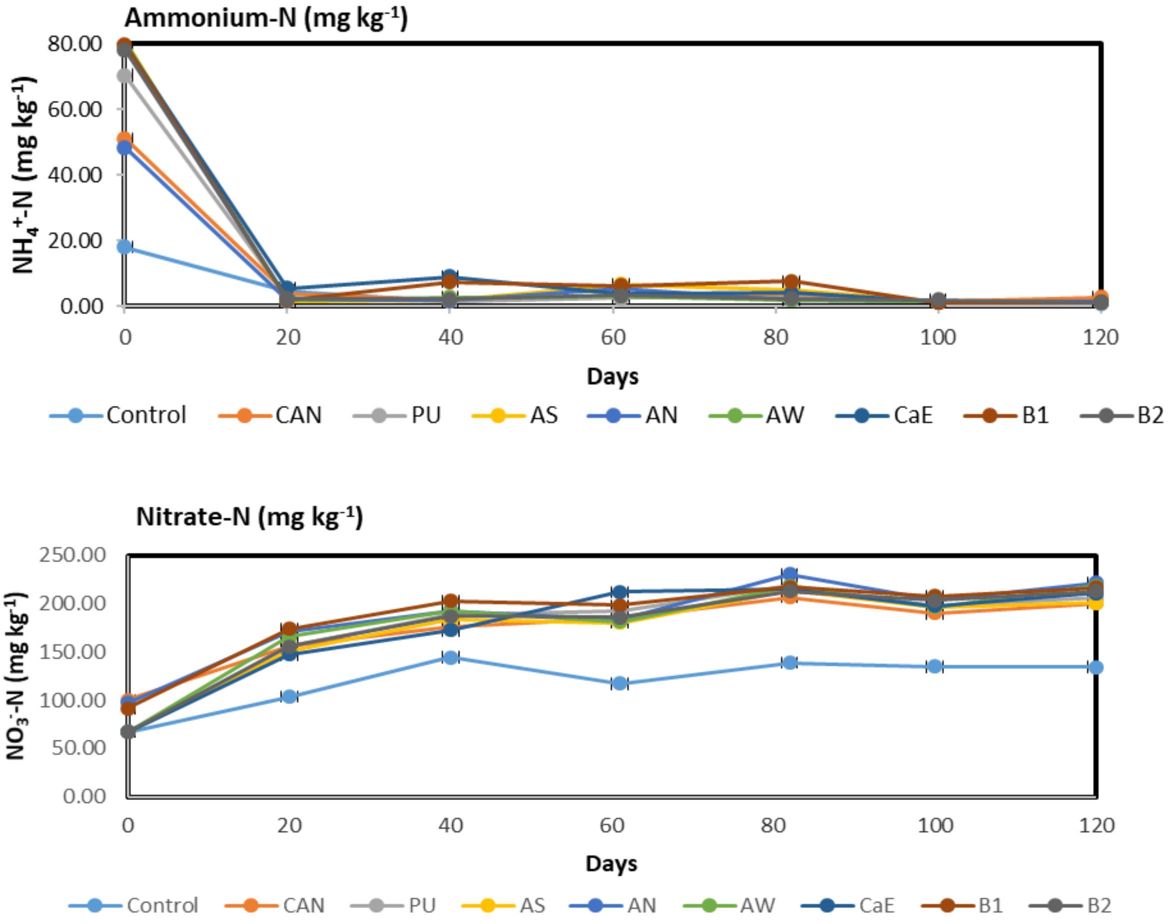
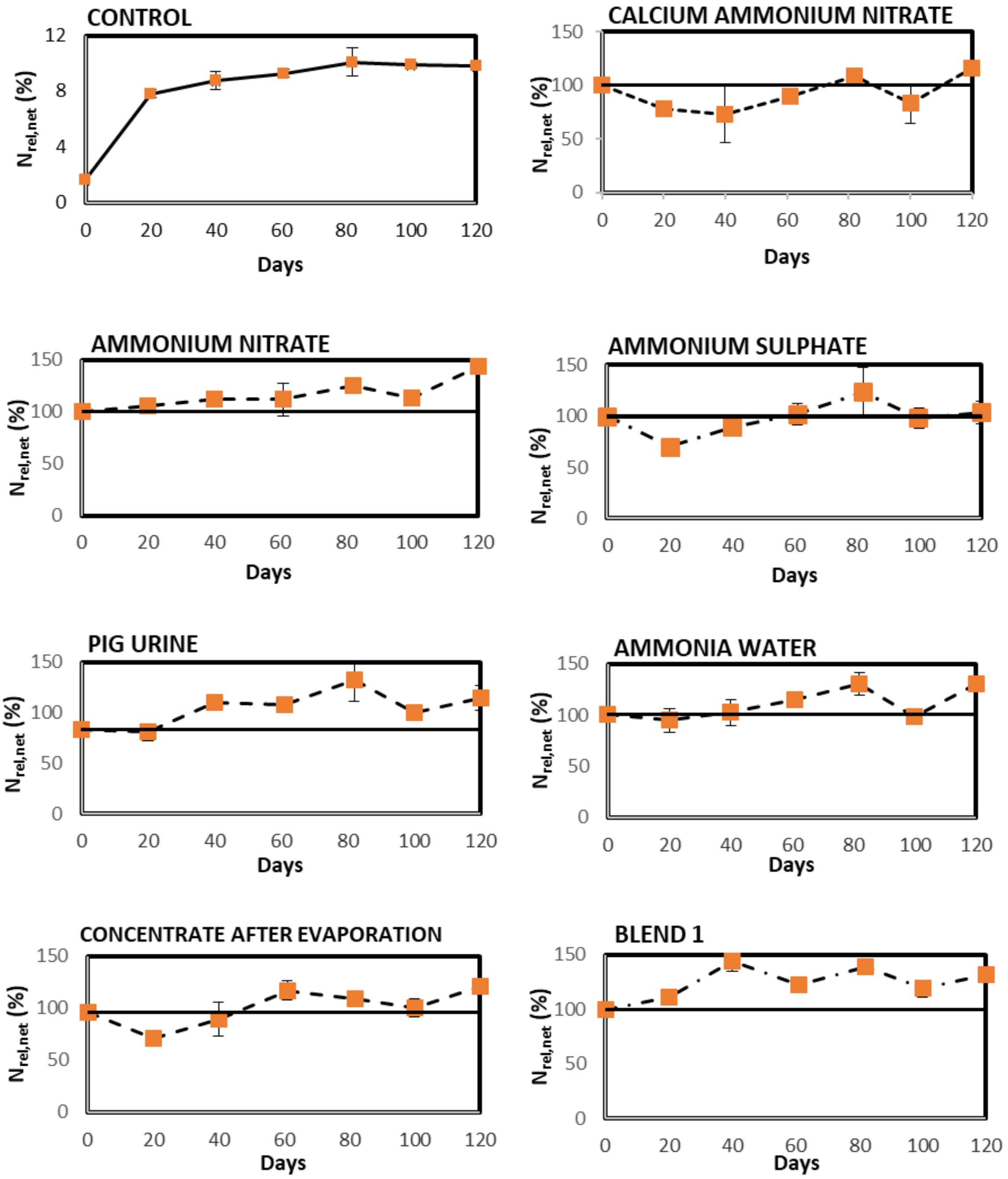


Figure 2-2. Evolution of mineral N (mg kg^{-1}) in unamended (control) and amended soil treated with RDFs and synthetic N fertiliser CAN during the 120-day incubation experiment (n = 3). Standard deviation is indicated by the error bars. CAN : calcium ammonium nitrate; PU : pig urine; AS : ammonium sulphate; AN : ammonium nitrate; AW : ammonia water; CaE : concentrate after evaporation ; B1 : blend 1; B2 : blend 2.

2.3.2 N release

For each treatment tested, the $N_{rel,net}$ as a percentage of the the total added N is presented in Figure 2-3. For day 120, AN exhibited the highest $N_{rel,net}$ amounting to 144 ± 8 %, followed by B1 displaying a $N_{rel,net}$ of 132 ± 5%. Treatments with AW (130 ± 4 %), B2 (129 ± 6 %), CaE (121 ± 5 %), CAN (116 ± 4 %), PU (115 ± 12 %), and AS (104 ± 11 %) exhibited $N_{rel,net}$ in the stated order respectively. All the tested RDFs showed average $N_{rel,net}$ greater than 100 %, and AN, AW, CaE, B1 and B2 displayed higher $N_{rel,net}$ higher than the synthetic CAN on day 120.



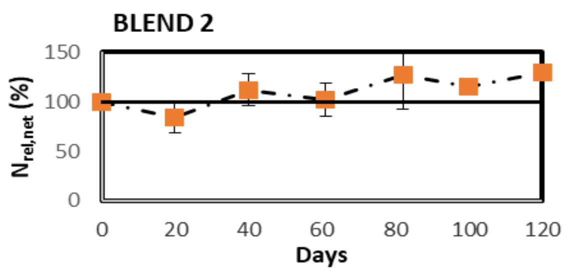


Figure 2-3. Net N release ($N_{rel,net}$ (%)) relative to the N input of added materials in a 120-day incubation experiment. The value plotted at t = 0 for treatments indicates the percentage of mineral N in the applied material and is presented as a straight line throught the experimental duration.
Net N mineralisation is indicated by the values plotted above this line and net N immobilisation is indicated by values below the line. Standard deviation is indicated by the errors bars (n = 3).

On an average basis, during 120 days of the incubation, highest $N_{rel,net}$ was exhibited by treatment with B1 (128 ± 12) followed by treatment with AN (119 ± 14 %). Treatments with AW (112 ± 16 %), B2 (111 ± 17 %), PU (108 ± 17 %), CaE (101 ± 19 %) and AS (98 ± 18 %) all had on average higher $N_{rel,net}$ in comparison to CAN (92 ± 17 %). Analysis was repeated for treatments where high standard deviations were observed between replicates. Nonetheless, inexplicable differences were still detected within replicates of treatments like AS and PU.

Most RDFs, albeit containing entirely mineral forms of N, were tested in this experiment because despite their mineral N form, none of these products are legally recognised as substitutes of synthetic N fertilisers. This experiment tested two high- (AN and AS) and one low-priority (PU) 'recovered nitrogen from manure' (RENURE) products as categorised by the Joint Research Centre (JRC) of the European Commission (Huygens et al., 2020) in an attempt to compare their performance potential against synthetic N fertilisers.

2.3.3 N mineralisation

The $N_{min,net}$ of amended treatments on day 120 of the experiment is expressed as a percentage of the total N applied. This was obtained as the difference between $N_{rel,net}$ (%) at a given sampling moment and $N_{rel,net}$ (%) at t = 0 (as explained in section 2.2.4). Highest mineralisation was observed in AN (44 ± 8 %) treatment, followed by B1 (32 ± 5 %), PU (31 ± 12 %), AW (30 ± 4 %), B2 (29 ± 6 %), CaE (25 ± 5 %), CAN (16 ± 4 %), and AS (4 ± 11 %) treatment. The amount of applied organic N differed greatly between the products and most of the tested RDFs were completely inorganic in nature (Table 2-4). Treatments with PU and CaE contained some organic N and B1 and B2 contained some negligible amounts of organic N owing to the contribution from CaE. There was no organic N contribution from any other tested treatments.

Table 2-4. The $N_{organic}/N_{total}$ content of different RDFs expressed in %.

	CAN	AN	AS	PU	AW	CaE	B1	B2
$N_{organic}/N_{total}$ (%)	0	0	0	16	0	3.9	0.21	0.11

Despite the complete lack of organic N, soil amended with AN and AW, and with the negligible amounts of organic N, soil amended with B1 and B2, showed N mineralisation. An increased mineral N as a result of transformation of soil organic N has been studied due to addition of N fertilisers in the soil (Kuzyakov et al., 2000), called the priming effect. It could be assumed that the increased mineralisation seen in the case of amended soil in this experiment was due to this priming effect induced by the respective RDFs on the soil.

During initial period of the experiment, it was observed that except for soil amended with AN and B1, all other treatments showed N immobilisation until day 40. Soil amended with the synthetic fertiliser CAN showed immobilisation until day 61.

2.4 Conclusion

N release and mineralisation are two parameters that can help to identify the effectiveness of a RDF as a N fertiliser. They also help in determining the potential of a RDF to substitute synthetic N fertilisers. In this experiment, five RDFs, i.e. AN, AS, PU, AW and CaE, and their two blends, B1 (AN + CaE) and B2 (AW + CaE) were tested to compare their $N_{rel,net}$ and $N_{min,net}$ pattern with that of synthetic N mineral fertiliser, CAN. It was seen that, on day 120 of the experiment, AN had the highest $N_{rel,net}$, followed by B1. AW, B2 and CaE exhibited N release higher than CAN. The overall $N_{rel,net}$ was highest for B1 followed by AN, AW, B2, PU, CaE and AS - all tested RDFs showed on average higher $N_{rel,net}$ than CAN during the entire period of the incubation experiment.

Following the $N_{rel,net}$ pattern, $N_{min,net}$ was also seen to be highest in AN followed by B1. These two treatments showed only mineralisation throughout the 120 days, presumably caused by the priming effect of the RDF application on the soil. All the treatments showed immobilisation until day 40, with CAN showing immobilisation until day 60. The results from this experiment could be used to emphasise on the suitability of RDFs like AN as a potential substitute for synthetic N fertilisers.

3. Carbon and nitrogen incubation experiment by Arvalis

3.1 Introduction

As the French partner in the ReNu2Farm project, Arvalis-Institut du vegetal, focussed on analysing and understanding RDFs that are, or might be used by farmers in France.

Thanks to the new European Fertiliser Regulation EU 2019/1009 laid down on the 5th of June 2019, more RDFs may be allowed to cross the French border. It is then essential to give farmers information on these products to help them understand the behavior of these RDFs after application in soil. Since composts from animal manure, especially from pig slurry and poultry manure, are increasingly used by farmers, especially those who are close to the Belgian and the German border, Arvalis focused on these products to study the N and C dynamics of these RDFs in soil. Incubation experiments were performed to study the N and C fertiliser behaviour of the composts derived from pig and poultry manure, by assessing the mineralisation patterns of these organic RDFs in the soil. Arvalis subcontracted this task to a certified laboratory called Aurea Agrosciences, and the set-up of the experiment and subsequent analyses were performed by this laboratory.

3.2 Materials and methods

3.2.1 RDFs tested in experiment

In collaboration with Deleplanque, three composts were selected. The choice of these three products was driven by the following factors :

- Raw materials for the production of composts should be imported from other European countries : the Netherlands and Belgium.
- These composts are a mix of poultry manure and pig slurry in different proportions.
- In France, composts made solely from either pig slurry or poultry manure are well known and characterised, but those made from a mix of these two raw materials raise questions. Do they behave closely to the main components of the composts? Does a single component independently guide the behaviour of the mixture?

The three chosen composts are described in Table 3-1. Deleplanque is a French enterprise that produces and sells composts since 1960. First, the products came from the sugar beet industry, then Deleplanque made products from raw materials coming from different European countries (such as composted pig slurry, or composted hen droppings). Nowadays, this enterprise sells mineral, organic and organo-mineral fertilisers. Deleplanque works with different producers in Europe (e.g. FITA in Belgium), to import raw materials into France, afterwhich, they develop and formulate the products. All of them respect the French legislation - either they are in compliance with the European regulation EU 2003 / 2003, or they are in compliance with French normalisation (NFU 42-001/ 44-051/ 44-095), or they are certified by the French Agency for Food, Environmental and Occupational Health and Safety (ANSES) as a 'MFSC' (Matières Fertilisantes et Supports de Culture = fertilising material and crop support).

Table 3-1. Description of the three composts tested in incubation experiments

RDF code	Under French normalisation	Composition and % of each raw material	Pig slurry origin	Poultry manure origin	Composting*
LiPo30	NFU 44-051	Compost made from a mix of SF of pig slurry (30%) and poultry manure (70%)	SF of pig slurry from mechanical separation (NL or BE)	BE	Composting after mixing
LiPo70	NFU 44-051	Compost made from a mix of SF of pig slurry (70%) and poultry manure (30%)	SF of pig slurry coming from mechanical separation (NL or BE)	BE	Composting after mixing
LiPo100	NFU 42-001	Compost of SF of digestate made from pig slurry	Mechanical separation of digestate (NL)	n.a.	Composting after mechanical separation

*Composting was done in compliance with the European Regulation CE 1069/2009
RDF: recycling-derived fertiliser; NFU: French normalisation; SF: solid fraction; NL: the Netherlands; BE: Belgium; n.a.: not applicable

3.2.2 RDF characterisation

The three composts were analysed by a certified laboratory (AUREA Agrosciences) in order to characterise their nutrient composition. Several analyses were performed at different moments (Table 3-2), depending on the use of the composts in the field trials, i.e. they were analysed just before fertilising each field trial. Two different batches of these products were sent by Deleplanque to Arvalis : first in 2018 to perform the field trials in 2018 and 2019 and the second batch in 2020 for the same year's field trials. Field trials are not reported or discussed in this deliverable, since this deliverable of focusses on laboratory testing (i.e. N and C incubations), and field trials are decribed and reported in WPT2 that deals with testing of RDFs in crop settings.

Table 3-2. Laboratory analyses done on the three composts.

Date	Batches	Analyses
26/11/2018	Batch 2018 : just before N field trial	Physico-chemical characteristics: N, P, K, Mg, Ca, Na, S composition
12/02/2019	Batch 2018 : 3 months of storage, just before 2019 P field trial	Physico-chemical characteristics: N, P, K, Mg, Ca, Na, S composition
22/03/2019	Batch 2018 : 4 months of storage	Physico-chemical characteristics: N composition; Incubations : IROC, C and N mineralisation
04/03/2020	Batch 2020 : just before 2020 P field trial	Physico-chemical caracteristics: N, P, K, Mg, Ca composition Incubations: IROC

IROC: indicator of Remaining Organic Carbon

The results of the analyses are presented and discussed in WP1_D3.1 *Report on mineral nutrient composition of analysed recycling-derived fertilisers*. Table 3-3 summarises the physicho-chemical tests performed on the RDFs by the laboratory and Tables 3-4 and 3-5 gives an extract from WP1_D3.1 of the results on characterisation of the three tested RDFs.

Table 3-3.: Physico-chemical parameters of RDFs analysed in the laboratory

Parameters	Method used
pH	pH measured is water pH; the laboratory refers to the French norms number NF EN 13037 or NFU 44172
DM	DM is measured according to the European and French norm: NF EN 13040
OM	OM is measured according to the European and French norm: NF EN 13039
N_{total}	N was measured (Dumas N) according to the European and French norm: NF EN 13654-2. N was measured in g/kg of fresh product and in g/kg of dry product.
NH_4^+-N and NO_3^--N	NH_4^+-N and NO_3^--N were measured by a method developed by Aurea laboratory, using KCl extraction. They were measured in g/kg of fresh product and in g/kg of dry product.
OC	OC is measured according to the European and French norm: NF EN 13039. It is measured as a % of the DM.
P, K, S, Na, Ca, Mg	The analyses provides the oxide forms for the macro- and micronutrients measured: P_2O_5; K_2O; SO_3; Na_2O; CaO; MgO were measured according to a method developed by Aurea, adapted from NF EN 13650, dosage from FN EN ISO 11885.

DM: dry matter; OM: organic matter; NF EN: Norme Francaise (French norm) European norm; NH_4^+-N: ammonium nitrogen; NO_3^--N: nitrate nitrogen; OC: organic carbon; P_2O_5: phosphorus (V) pentoxide; K_2O: potassium oxide; SO_3: sulphur trioxide; Na_2O: sodium oxide; CaO: calcium oxide; MgO: magnesium oxide

Table 3-4. Characterisation of recycling derived fertilisers on dry matter basis

Products	LiPo100	LiPo100	LiPo70	LiPo70	LiPo30	LiPo30
Batch	2018	2020	2018	2020	2018	2020
pH (water)	9.2	8.9	8.8	9.1	8.8	8.7
% DM	49	32	59	32	31	37
OC (%)	28	35	33	34	36	37
OM (%)	56	70	65	68	72	73
C/N_{total}	8.4	12	7.1	8.6	7.8	7.9
C/N_{org}	8.8	13	8.7	12	11	11
Total N (g/kg)	33	29	46	39	46	47
NH_4^+-N (g/kg)	1.4	3.3	8.8	11	12	14
NO_3^--N (g/kg)	0.14	<0.01	<0.01	<0.01	<0.01	<0.01
Organic N (g/kg)	32	26	37	28	34	32

DM: dry matter; OM: organic matter; NH_4^+-N: ammonium nitrogen; NO_3^--N: nitrate nitrogen; OC: organic carbon

Table 3-5 Characterisation of RDFs on fresh matter basis

Products	LiPo100	LiPo100	LiPo70	LiPo70	LiPo30	LiPo30
Batch	2018	2020	2018	2020	2018	2020
OM (%)	27	23	38	22	23	27
Total N (g/kg)	16	9.5	27	13	15	17
NH_4^+-N (g/kg)	0.7	1	5.1	3.6	3.8	5.2
NO_3^--N (g/kg)	0.07	<0.01	<0.01	<0.01	<0.01	<0.01
Organic N (g/kg)	15	8.5	22	9	11	12

OM: Organic matter; NH_4^+-N: Ammonium nitrogen; NO_3^--N: Nitrate nitrogen; OC: Organic carbon

3.2.3 Incubation set-up

Soil incubation experiment to test the organic RDFs in laboratory was done in compliance with the French normalisation : XP U44-16. The objective of this laboratory test is to estimate the C and N mineralisation potential of organic products. The results of this test help in assessing the kinetics of C and N mineralisation. In France, many organic products have been characterised and tested using this method. The results of the three RDFs tested in this experiment are compared to the values of reference classifications of organic fertilisers (i.e. documented characterisation of organic fertilisers, see Figure 3.2). OC and organic N are measured in standardised and controlled conditions.

The protocol for N and C incubations involved the following :

- Mixing of the RDF and soil
    - Soil chosen for the experiment had the following properties :
        - Water pH : 6.0 - 7.3
        - Clay content (%) : 15 - 25
        - Calcium carbonate ($CaCO_3$) (g/kg) : <2
        - OC (%) : 0.5 - 1
    - The RDF was incorporated in order to have 2 g of OC per kg of dry soil.
- Incubation conditions
    - Incubation was done in an oven under controlled humidity (wilting point 2.8) and at a temperature of 28°C for 91 days. The period of 91 days in such controlled conditions is analogous to two years in field conditions.
- Measurements
    - The parameters evaluated during the experiment are stated in Table 3-6.

Table 3-6. Different parameters evaluated during the soil incubation experiment

Carbon kinetics	Nitrogen kinetics
Measurements of carbon dioxide (CO_2) emission	Extraction and measurements of mineral N (NO_3 + NH_4)
Measurements are done on the mix (soil + RDF) and on a control (only soil)	Seven measurements during the incubation period
Nine measurements during the incubation period	

3.3 Results

3.3.1 N mineralisation

Incubation tests were done on the three composts in 2019. The results of these tests are presented in Appendix (A-1-1 for LiPo 30, A-2-1 for LiPo 70, A-3-1 for LiPo 100). Figure 3-1 below shows the organic N mineralisation kinetics of the three tested RDFs. During the test (91 days at 28°C), 17 % of organic N mineralised for LiPo 30, 29 % of organic N mineralised for LiPo 70 and 16 % of organic N mineralised for LiPo 100.

In order to compare field trials between them or with laboratory tests, or to compare laboratory tests with real conditions, a notion to normalise the time regarding climatic and soil humidity conditions is used. This procedure is described in the document edited by the COMIFER in 2013: *Calcul de la fertilization azotée, guide méthodologique pour l'établissement des prescriptions locales.* One normalised day is one day at 15°C with the soil at field capacity. For a site, and a given period, the calculation of the number of normalised days is the multiplication of a temperature function (f(T)) and a soil humidity function (f(H)). f(T) is an exponential function which is equal to 1 at 15°C. f(H) is a linear function between wilting point and field capacity. It is equal to 1 at field capacity and 0.2 at the wilting point. One year in real conditions in France is about 220 normalised days. We can also estimate that about 50 days of the laboratory incubation test at 28°C and field capacity represent one year under field conditions. Using the notion of normalised days and the results of incubation tests (Figure 3-1), we can estimate that during a year in real condition:

- 10 % of organic N mineralised for LiPo30
- 26 % of organic N mineralised for LiPo70
- 14 % of organic N mineralised for LiPo100

This represents the amount of organic N that can be provided by the three composts during a year. To be more accurate, the growing period of the crop on which the organic product is applied should be taken into account. The kinetics also give us information on when the N could be available for the crops under laboratory conditions.

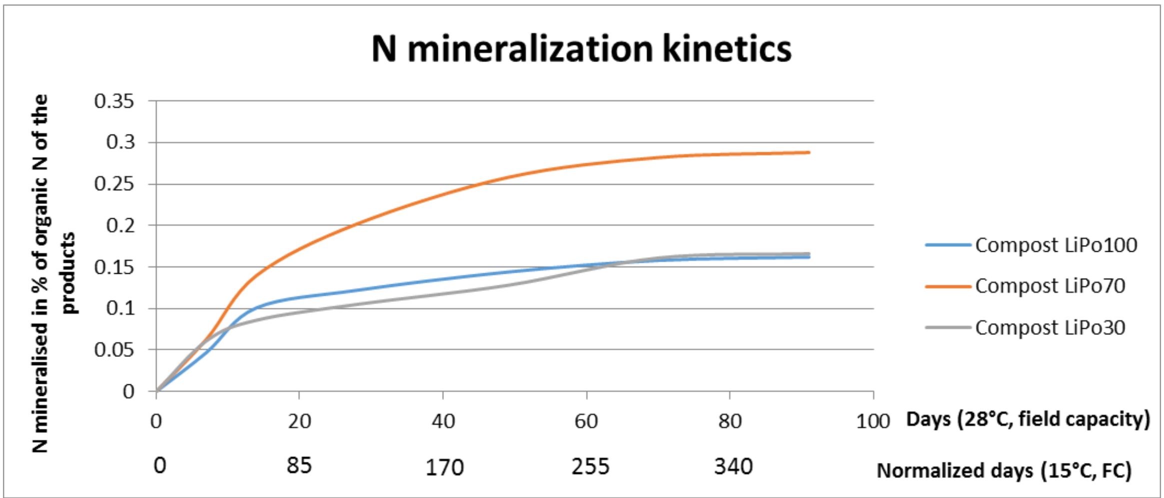


Figure 3-1. N mineralisation kinetics measured for the three composts in laboratory under the French normalisation XP U44-16.

Finally, the tested composts were compared to the data available from past research. In France, a project conducted by Arvalis Institut du vegetal and INRAe in 2008 (Bouthier et al., 2009) aimed to better characterise the N mineralisation of organic products. During this project, 68 organic products were tested in field trials (28 sites in France and Belgium) and 44 organic products were incubated in laboratory. 44 kinetics of N mineralisation in field and in laboratory were analysed and compared. These tests lead to classify the N behaviour of different organic products into six classes. These six classes are used in France to estimate the N efficiency of organic products in different decision support tools used by farmers. It is then of interest to compare the N kinetics of the three composts to the six classes and especially to the mineralisation of the raw materials that are components of the three composts (Figure 3-2 and Figure 3-3). The raw materials of the three composts are:

- Pig slurry -> class 3
- Poultry manure -> class 4
- Digestate of pig slurry -> class 3 to 2

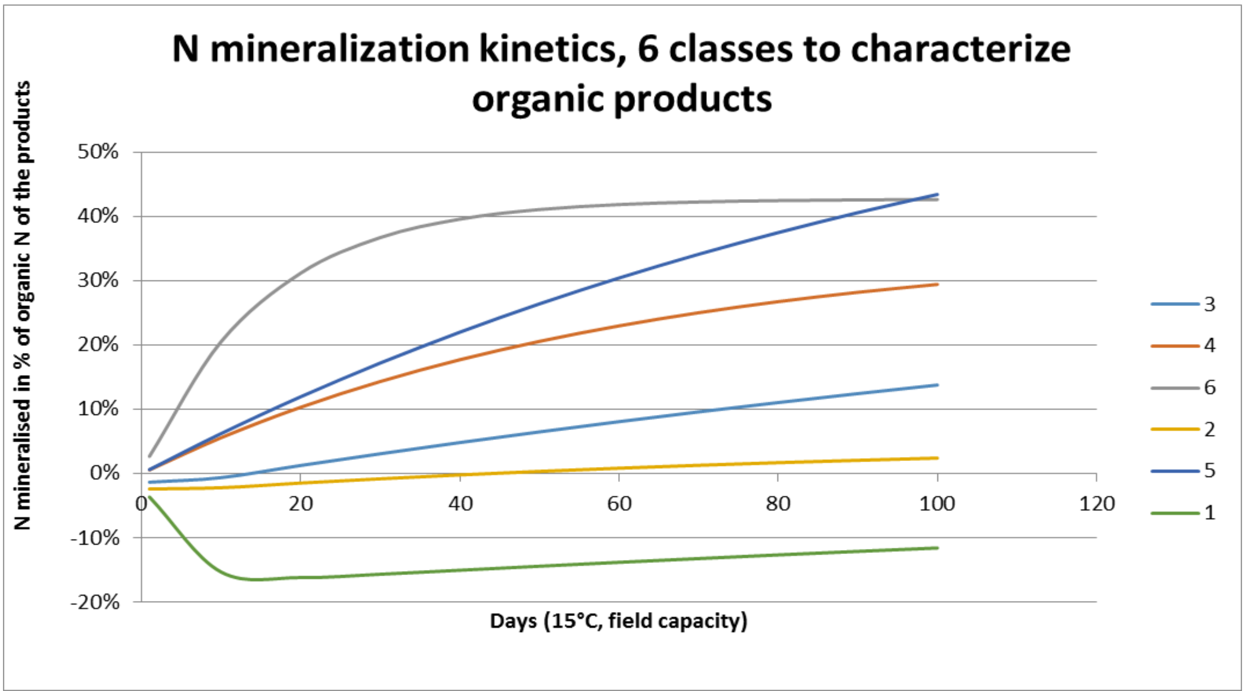


Figure 3-2. Six classes of N mineralisation kinetics, Arvalis institut du vegetal and INRAe, 2009. Class 1: Composted bovine manure, composted green waste; Class 2 : Composted manure (bovine and porcine), composted green waste, composted green waste + sludge; Class 3 : Manure (bovine and porcine); Class 4 : Poultry manure; composted poultry manure, dried urban sludge; Class 5 : Concentrated vinasse; Class 6 : Hen droppings. Digestates are classified between class 2 and 3.

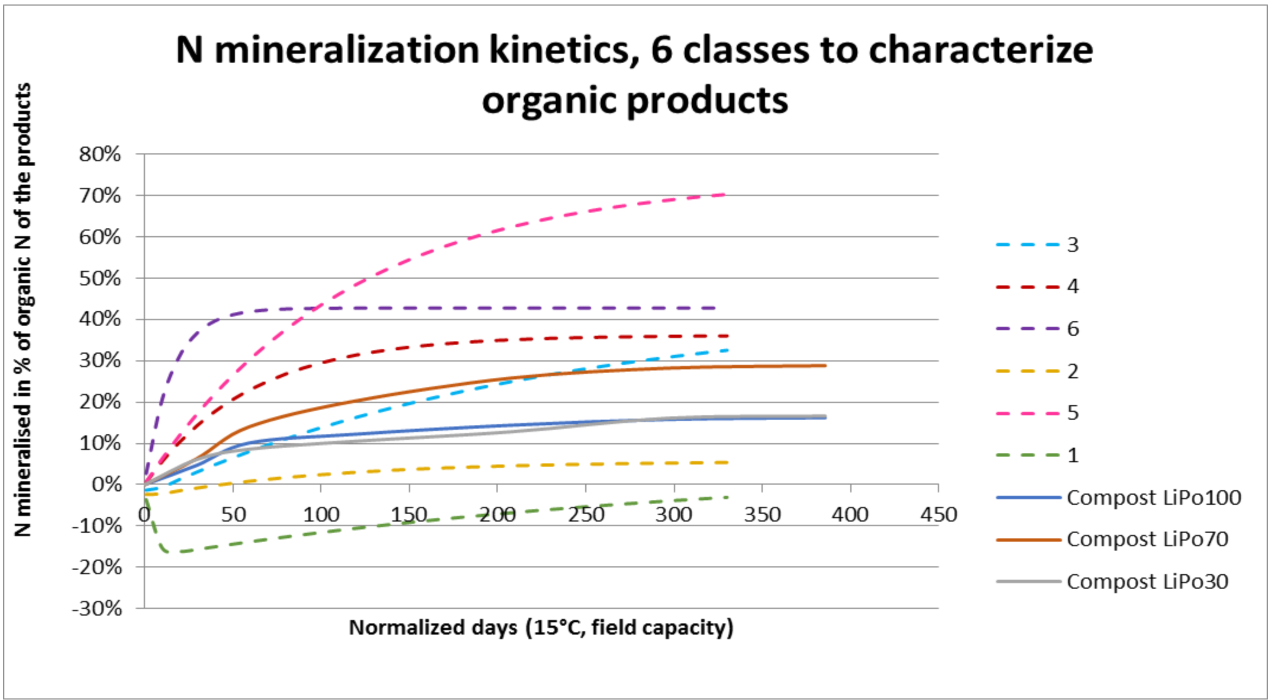


Figure 3-3. The positioning of the three composts in regard to the six classes of organic products

LiPo100 seems to have a behaviour between class 2 and 3 (Figure 3-3). The first days of mineralisation were closer to Class 3, but the whole kinetics is closer to the behaviour of Class 2. As this compost is made from a digestate, it was expected to be between Class 2 and 3, which is in agreement with other studies (*Arvalis institut du vegetal and INRAe, 2009*). Therefore LiPo100, a compost made from a digestate of pig slurry, can be linked with class 2.

LiPo70 seems to have a behaviour between Class 3 and 4, whereas LiPo30 seems to have a behavior between Class 3 and 2. It was expected that LiPo70 (a compost made from 70 % of pig slurry) would behave more like Class 2, while LiPo30 (a compost made from 70 % of poultry manure) would behave more like class 4. These results need to be confirmed, especially for LiPo70. In Tables 3-4 and 3-5 the instability of this product can be seen which could be explained by the composting process or the storage of the product.

In order to complete these results, data from other incubation experiments conducted by Deleplanque were consulted. Data available from Deleplanque confirms the N behaviour of LiPo30 measured in the experiment conducted for the ReNu2Farm Project and presented in Figure 3-3. The product is confirmed to behave between Class 3 (manure (bovine and porcine)) and Class 4 (poultry manure; composted poultry manure, dried urban sludge). It seems that the poultry manure has more influence than pig slurry on the N behaviour of this compost. Therefore, a link could be made between the compost made from poultry manure or partly made from poultry manure to class 4. This conclusion would need to be confirmed.

3.3.2 C mineralisation

Incubation tests were done on the three composts in 2019 (Figure 3-4). The results of these tests are presented in Appendix (A-1-2 for LiPo 30, A-2-2 for LiPo 70, Paragraph A-3-2 for LiPo 100).

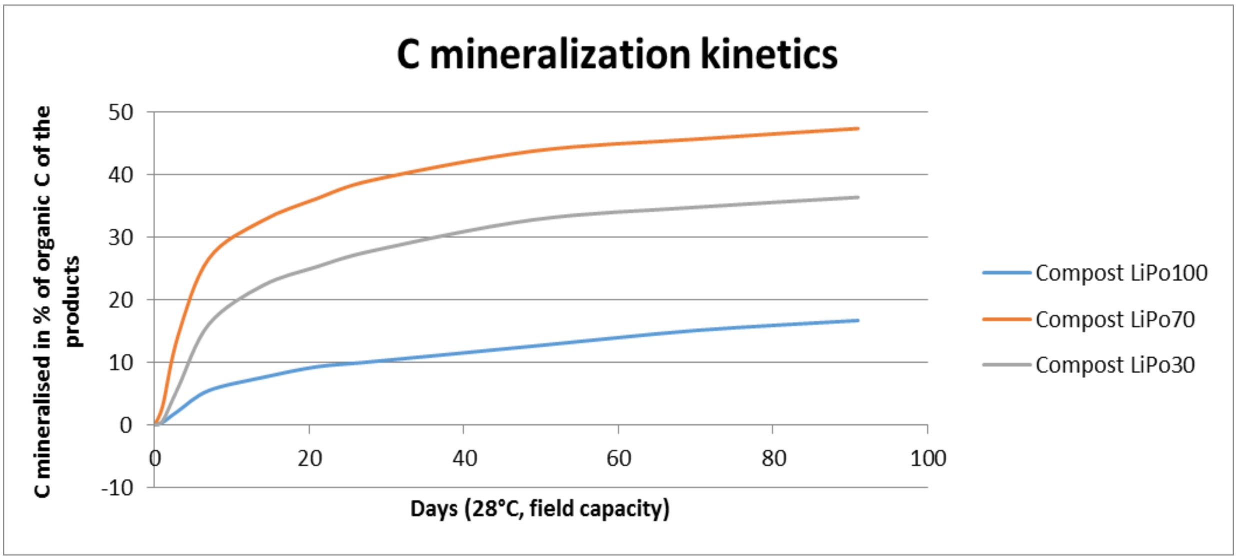


Figure 3-4. Carbon mineralisation kinetics of the three composts.

Figure 3-4 represents the labile C of the organic products in percentage of OC in the compost. The non mineralised C that can be calculated by the formula *100 – (% C mineralised)* represents the percentage of OC that is the most stable and may contribute to improve content of soil OM. According to the results (Figure 3-4), LiPo100 has shown to be the most stable product, since the lowest amount of C was mineralised from it. Since this product is made from a digestate, this result was expected and is in agreement with other studies which reports that digestate is quite a stable product (Thomson et al. 2013; Vadimethan project, 2014).

3.3.3 Indicator of residual organic carbon

3.3.3.1 Why look at IROC?

As explained by Levavasseur et al. (2020), the indicator of residual organic carbon (IROC) proposed by Lashermes et al. (2009) is calculated from biochemical fractions of Exogenous Organic Matter (EOM) (Van Soest and Wine 1967) and the proportion of C in EOM that is mineralised during a very short incubation period (three days). IROC has been defined as a predictor of the residual EOM C after a long-term incubation of EOM with soil under controlled conditions.

IROC presented in the section 3.3.3.2 is defined as a good predictor of the C mineralisation results described in part 3.3.2. Laboratories measure IROC more routinely than C mineralisation with long-term incubations. Hence, it is of interest to look at this value to describe the three composts.

3.3.3.2 Materials and methods

IROC measurement is based on a characterisation of OM by successive solubilisations. The aim is to first divide the organic product in several biochemical components such as soluble fraction (SOL), hemicellulose fraction (HEM), cellulose fraction (CEL), and lignin-like fraction (LIC), in g/kg total OM. This analysis is done on a sample previously dried at 38°C and ground at 1 mm. The organic fractions are then used to calculate an index (IROC) which determines, a priori, in the organic product, the proportion of OM that could potentially be resistant to mineralisation. The proportion of each fraction helps to estimate the stability of the product. IROC also takes into account the proportion of OC mineralised during three days in the test presented in section 3.2.2. IROC measurement is normalised in the French norm XP U44-162, December 2009. IROC is expressed in percentage of total OM. The higher the IROC is, more stable the product is and it contributes more to improvement of the soil OM rate. IROC is determined according to Lashermes et al. (2009) as follows :

$$IROC = 445 + 0.5\ SOL - 0.2\ CEL + 0.7\ LIC - 2.3\ Cm3 \quad \text{(Eq.3)}$$

Where,

SOL= soluble fraction in g/kg total OM,

HEM = hemicellulose fraction in g/kg total OM,

CEL = cellulose fraction in g/kg total OM,

LIC = lignin-like fraction in g/kg total OM,

Cm3 = C mineralised during the first 3 days of the mineralization test described in the norm XP U44-16.

3.3.3.3 Results

As mentioned in the previous section, IROC is more routinely analysed by laboratories than C mineralisation measurements during 91 days, so, IROC was measured for the 3 composts on two different batches in 2019 and 2020 (Table 3-7). The results of these tests are also presented in Appendix (A-1-3 and A-1-4 for LiPo30, A-2-3 and A-2-4 for LiPo70 and A-3-3 and A-3-4 for LiPo100).

Table 3-7: IROC measurements for the three composts

Date of measurement	Product code	IROC (% OM)
29/06/2018	LiPo30*	54
22/03/2019	LiPo30 (2019)	61
04/03/2020	LiPo30 (2020)	34
22/03/2019	LiPo70 (2019)	42
04/03/2020	LiPo70 (2020)	46
09/08/2016	LiPo100*	63
08/01/2018	LiPo100*	73
22/03/2019	LiPo100 (2019)	76
04/03/2020	LiPo100 (2020)	64

*Data from Deleplanque

3.3.3.4 Discussion

As explained in the first two sections of 3.3.3, IROC is correlated as C mineralisation after 91 days of incubation. Hence, the aim is to investigate if this correlation was observed in 2019 for the batch on which both data were measured. Results have shown that correlation was observed for the three tested composts between IROC and C incubation (Figure 3-5). Levavasseur et al. (2018), in the project SOLEBIOM, compared IROC of different organic products. The results are presented in Figure 3-6.

LiPo100 with a mean value of 69 for its IROC is the most stable product. It can be observed from Figure 3-6-a that this value is close to the mean IROC value for compost. This product will bring stable OM to the soil and this OM in turn will contribute to the improvement of soil OM and C storage.

LiPo70 IROC with a mean value of 44 is the same for the two batches tested. This compost has a low IROC compared to other compost presented in Figure 3-6-c.

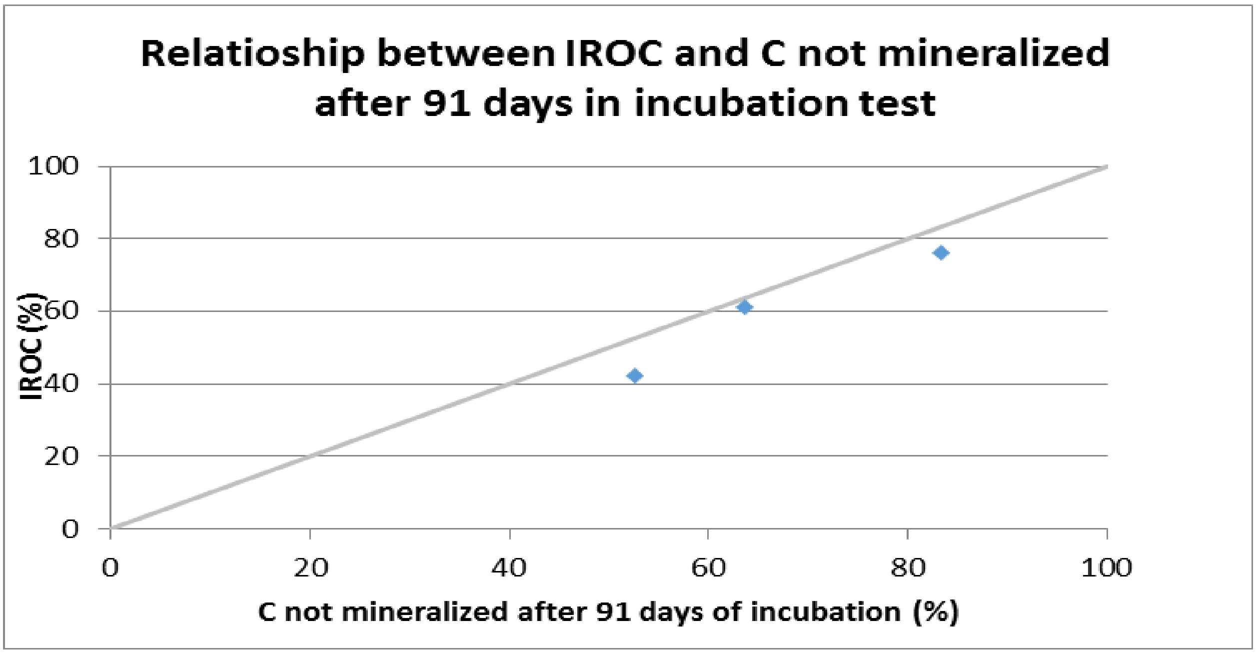


Figure 3-5. Relationship between IROC and non mineralised OC after 91 days of incubation

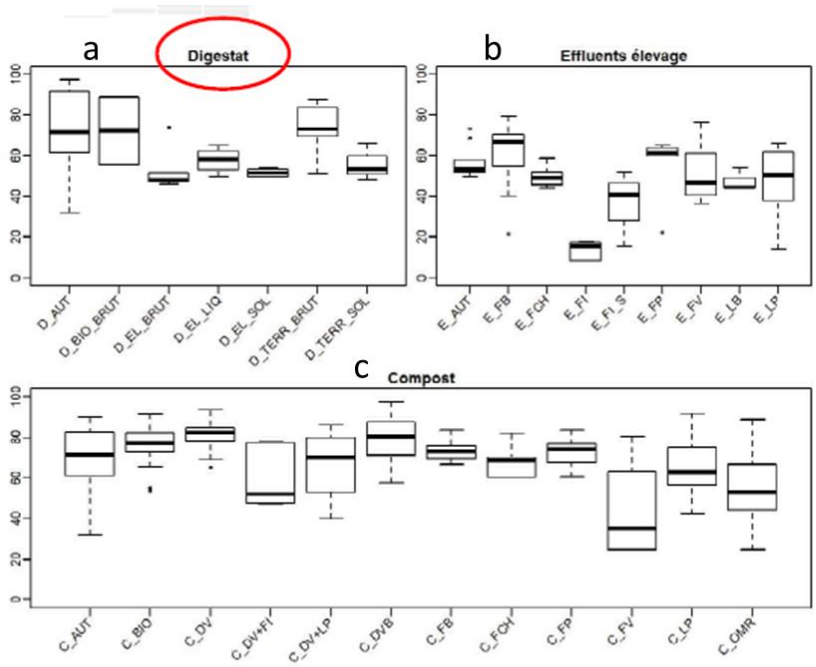


Figure 3-6. IROC of different organic products. a) Digestat represents IROC measurements and variability for for seven groups of digestates. b) Effluents élevage represents IROC measurements and variability for for nine groups of manure. c) Compost represents IROC measurements and variability for 12 groups of composts. Source : Levavasseur et al., SOLEBIOM project, 2018)

For LiPo30, the measurements done in 2019 and 2020 on two different batches show quite different values with a stable product in 2019 and a more labile product in 2020. This could be explained by the composting process which might not have been fully completed in 2020. When looking at the composition analyses of the product in 2019 and 2020, we can see that NH_4^+-N is higher in 2020 than in 2019. This might indicate that in 2020, the composting process was incomplete in comparison to 2019.

Furthermore, Levavasseur et al. (2020) found that IROC can be used to describe organic product mineralisation rate in the model AMG. AMG is a model developed to simulate SOC turnover (Andriulo et al. 1999). It can be used to predict SOC evolution in a field and it is useful to see the effect of different organic products on this SOC. AMG has been calibrated and validated for a range of cropping systems and pedoclimatic conditions (Bouthier et al. 2014; Clivot et al. 2019). It is now widely used in France. As a member of the AMG consortium, Arvalis implemented a tool called CHN-AMG to use this model.

IROC measurements will be used with soil measurements and agricultural practices of the field trials conducted in France and SOC storage will be simulated and presented in the deliverable WP2_2.3 *Report on environmental impact : nutrient and CO_2 emissions.*

3.4 Conclusion

N and C incubation measurements help to characterise and understand better the behaviour of the three composts tested. The comparison with commonly used N behaviour classification and IROC data base helps to characterise these products.

The lab measurements facilitates the studies to observe how the three composts can contribute to the N fertilisation with a release of 10 % (LiPo30), 26 % (LiPo70) and 14 % (LiPo100) of organic N within a year. That could represent about 1.1 g/kg of N for LiPo30, 5.7 g/kg of N for LiPo70 and 1.5 g/kg of N for LiPo100. With a dose of 10 tonnes of compost per hectare, the N potentially available for the crops is not negligible and will have to be taken into account in the N balance. These measurements were done only once on the three composts tested here, therefore, the study would need to be replicated to confirm the results. We can see variability within different batches in the replicated composition measurements. This point empasises on the need of provision of information by the producers to farmers to help them in using these organic RDFs optimally.

Regarding C behaviour, the C incubation and IROC measurements confirm the organic amendment effect of these composts. They will contribute to SOC storage. The quantification of C storage will be presented in the report in WP2_D2.3 *Report on environmental impact : nutrient and CO_2 emissions*.

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Appendix

A1. Laboratory report for N and C mineralisation measurements for the product LiPo30

A.1.1- N mineralisation for the batch tested in field trial in 2019

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ANALYSE RÉALISÉE POUR : RENUFARM 2018

ORGANISME : ARVALIS ESTREES MONS
DOMAINE INRA
80200 ESTREES-MONS

N° de laboratoire : 11816671

Référence échantillon
Référence : LIPO30
Commune :
Station :

Dates repères
Date de prélèvement :
Date de réception : 22/03/2019
Date de sortie : 05/08/2019

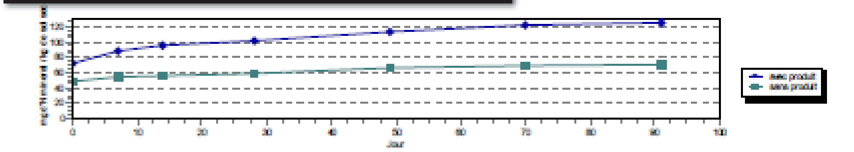
Échantillon analysé :
CDE RENUFARM2018/LAMPAERT/ESTREES MONS
Type produit : AMENDEMENTS ORGANIQUES

MINÉRALISATION DE L'AZOTE

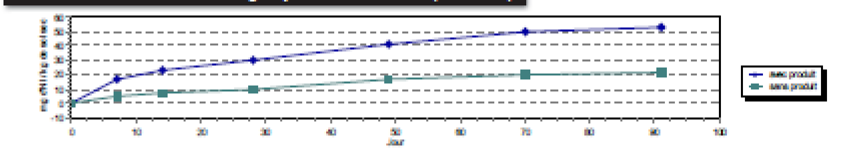
Résultats de la minéralisation de l'azote

	Unité		J0	J7	J14	J28	J49	J70	J91
Quantité d'azote minéral présent dans le sol sous forme NH_4 et NO_3	mg d'N minéral / kg de sol sec	avec produit	71.8	88.1	94.8	101.3	112.8	121.8	124.4
		sans produit	48.9	63.8	65.8	68.8	66.8	68.5	70.3
Minéralisation nette de l'azote organique en azote minéral (NO_3+ NH_4)	mg d'N minéral / kg de sol sec	avec produit	0.0	16.5	23.3	29.8	41.0	50.1	52.8
		sans produit	0.0	6.0	8.9	9.9	16.7	19.8	21.5
N minéralisé (+) ou immobilisé (-)	% d'azote organique du produit		0.0	6.1	8.8	10.5	12.8	16.1	16.8

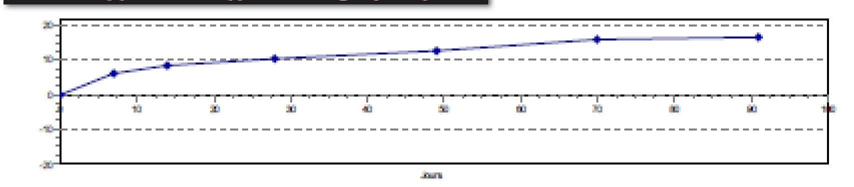
Quantité d'azote minéral présent dans le sol sous forme NH_4 et NO_3



Minéralisation nette de l'azote organique en azote minéral (NO_3 + NH_4)



N minéralisé (+) ou immobilisé (-) en % de N organique du produit



aurea AUREA - 270 Allée de la Pomme de Pin, 45160 Ardon Tél. 01.44.31.40.40 - Fax: 01.44.31.40.41

Interreg North-West Europe ReNu2Farm
European Regional Development Fund

A.1.2- C mineralisation for the batch tested in field trial in 2019

aurea AgroSciences

ANALYSE RÉALISÉE POUR :	ORGANISME :
RENUFARM 2018	ARVALIS ESTREES MONS DOMAINE INRA 80200 ESTREES-MONS

N° de laboratoire	Référence échantillon	Dates repères
11816671	Référence : LIPO30 Commune : Station :	Date de prélèvement : Date de réception : 22/03/2019 Date de sortie : 05/08/2019

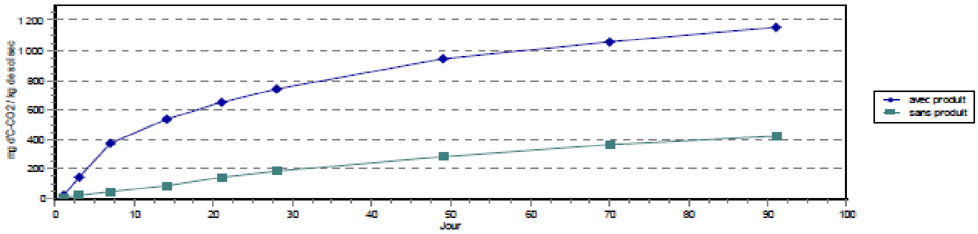
Échantillon analysé :
CDE RENUFARM2018/LAMPAERT/ESTREES MONS
Type produit : AMENDEMENTS ORGANIQUES

MINÉRALISATION DU CARBONE

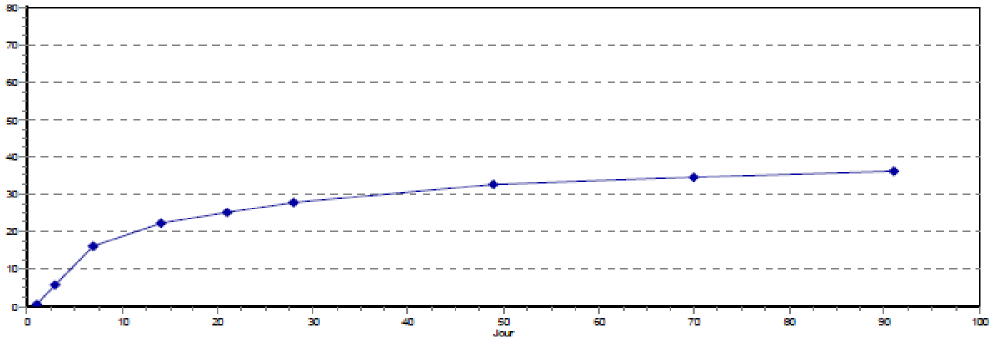
Résultats de la minéralisation du carbone

	Unité		J1	J3	J7	J14	J21	J28	J49	J70	J91
Quantité de C-CO_2 dégagé par le sol	mg de C-CO_2 / kg de sol sec	avec produit	21.3	145.3	372.6	537.1	649.4	740.0	941.0	1058.2	1153.9
		sans produit	8.2	27.8	49.5	91.0	143.6	183.4	284.1	362.4	425.7
Coefficient de minéralisation	% de carbone organique du produit		0.6	5.9	16.1	22.3	25.3	27.8	32.8	34.8	36.4

Quantité C-CO_2 dégradé par le sol



Coefficient de minéralisation exprimé en % sur C organique initial du produit



aurea AURÉA - 270 Allée de la Pomme de Pin, 45160 Ardon Tél. 01.44.31.40.40 - Fax. 01.44.31.40.41

A.1.3- C mineralisation for the batch tested in field trial in 2019: measurements of ISMO

Aurea AgroSciences

DEMANDEUR :

RENUFARM 2018

ORGANISME :

ARVALIS ESTREES MONS
DOMAINE INRA
2 CHAUSSEE BRUNEHAUT
80200 ESTREES-MONS

N° LABORATOIRE		
11816671		
Dates		
Prélèvement	Arrivée	Expédition
	22/03/2019	25/06/2019

MARQUE	
RÉFÉRENCE	LIPO30
N° LOT	
N° SCELLÉ / CODE BARRE	
RÉFÉRENTIEL	
TYPE PRODUIT	AMENDEMENTS ORGANIQUES

Evaluation de la stabilité biologique

Déterminations		Méthode	Résultats
Matière sèche (1)	% du produit brut	Méthode interne selon NF EN 13040	° 31.4
Matière organique (2)	% de matière sèche	Méthode interne selon NF EN 13039	71.78
NDF org.	% de la matière organique partiellement sec à 40 °C (insolubles dans le détergent neutre)	FD U44-162	55.74
ADF org.	% de la matière organique partiellement sec à 40 °C (insolubles dans le détergent acide)	FD U44-162	37.13
ADL org.	% de la matière organique partiellement sec à 40 °C (lignine sulfurique)	FD U44-162	17.35
* Composés organiques solubles (SOL)	% de la matière organique partiellement sec à 40 °C	FD U44-162	44.26
* Hemicelluloses (HEM)	% de la matière organique partiellement sec à 40 °C	FD U44-162	18.60
* Cellulose (CEL)	% de la matière organique partiellement sec à 40 °C	FD U44-162	19.78
* Lignines et cutines (LIC)	% de la matière organique partiellement sec à 40 °C	FD U44-162	17.35
Cellulose brute Weende (CEW)	% de la matière organique partiellement sec à 40 °C	XP U44-162	° 26.60
Carbone organique minéralisé à 3 jours	% du carbone organique	FD U44-163	5.88

ISB - Indice de Stabilité Biochimique	proportion de la matière organique	0.34
ISMO - Indice de Stabilité de la Matière Organique (3)	% de la matière organique	61.3
	kg de MO stable / t de matière sèche	440
	kg de MO stable / t de matière brute	138

Commentaire

1 tonne de produit brut pourrait fournir 138 kg de matière organique potentiellement résistante à la dégradation(calcul avec ISMO).
° : Les analyses ont fait l'objet d'une vérification.

Kg MO potentiellement résistante à la dégradation = (1) x 10 x (2) / 100 x (3) / 100

Interreg North-West Europe ReNu2Farm
European Regional Development Fund

A.1.4- C mineralisation for the batch tested in field trial in 2020: measurements of ISMO

aurea AgroSciences

DEMANDEUR :

CDE 5430-90-77150

ORGANISME :

ARVALIS BAZIEGE
6 CHEMIN DE LA COTE VIEILLE

31450 BAZIEGE

N° LABORATOIRE
2202174

Dates		
Prélèvement	Arrivée	Expédition
	04/03/2020	24/03/2020

MARQUE	
RÉFÉRENCE	28 RENU2FARM-COMPOST 1.8-2.2-1.6 (LIPO 30)
N° LOT	
N° SCELLÉ / CODE BARRE	
RÉFÉRENTIEL	
TYPE PRODUIT	AMENDEMENTS ORGANIQUES

Evaluation de la stabilité biologique

Déterminations		Méthode	Résultats
Matière sèche (1)	% du produit brut	Méthode interne selon NF EN 13040	36.8
Matière organique (2)	% de matière sèche	Méthode interne selon NF EN 13039	73.08
NDF org.	% de la matière organique partiellement sec à 40 °C (insolubles dans le détergent neutre)	FD U44-162	63.25
ADF org.	% de la matière organique partiellement sec à 40 °C (insolubles dans le détergent acide)	FD U44-162	42.17
ADL org.	% de la matière organique partiellement sec à 40 °C (lignine sulfurique)	FD U44-162	17.22
* Composés organiques solubles (SOL)	% de la matière organique partiellement sec à 40 °C	FD U44-162	36.75
* Hemicelluloses (HEM)	% de la matière organique partiellement sec à 40 °C	FD U44-162	21.09
* Cellulose (CEL)	% de la matière organique partiellement sec à 40 °C	FD U44-162	24.95
* Lignines et cutines (LIC)	% de la matière organique partiellement sec à 40 °C	FD U44-162	17.22
Cellulose brute Weende (CEW)	% de la matière organique partiellement sec à 40 °C	XP U44-162	33.39
Carbone organique minéralisé à 3 jours	% du carbone organique	FD U44-163	15.71

ISB - Indice de Stabilité Biochimique	proportion de la matière organique	0.28
ISMO - Indice de Stabilité de la Matière Organique (3)	% de la matière organique	33.8
	kg de MO stable / t de matière sèche	247
	kg de MO stable / t de matière brute	91

Commentaire

1 tonne de produit brut pourrait fournir 91 kg de matière organique potentiellement résistante à la dégradation(calcul avec ISMO).

Kg MO potentiellement résistante à la dégradation = (1) x 10 x (2) / 100 x (3) / 100

A2. Laboratory report for N and C mineralization measurements for the product LiPo70

A.2.1- N mineralisation for the batch tested in field trial in 2019

Aurea AgroSciences

ANALYSE RÉALISÉE POUR :	ORGANISME :
RENUFARM 2018	ARVALIS ESTREES MONS DOMAINE INRA 80200 ESTREES-MONS

N° de laboratoire	Référence échantillon	Dates repères
11816672	Référence : LIPO70 Commune : Station :	Date de prélèvement : Date de réception : 22/03/2019 Date de sortie : 05/08/2019

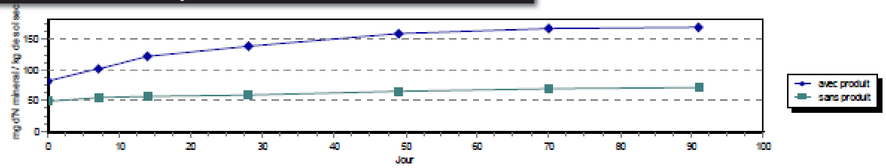
Échantillon analysé :
CDE RENUFARM2018/LAMPAERT/ESTREES MONS
Type produit : AMENDEMENTS ORGANIQUES

MINÉRALISATION DE L'AZOTE

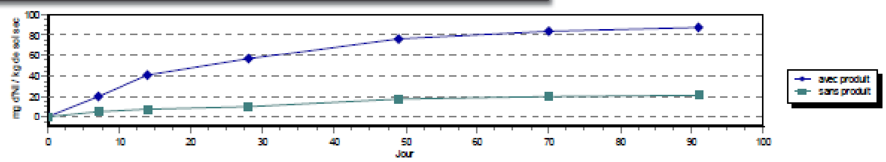
Résultats de la minéralisation de l'azote

	Unité		J0	J7	J14	J28	J49	J70	J91
Quantité d'azote minéral présent dans le sol sous forme NH_4 et NO_3	mg d'N minéral / kg de sol sec	avec produit	80.9	100.3	121.6	137.2	157.0	165.4	168.5
		sans produit	48.9	53.9	55.8	58.8	65.6	68.5	70.3
Minéralisation nette de l'azote organique en azote minéral (NO_3 + NH_4)	mg d'N minéral / kg de sol sec	avec produit	0.0	19.4	40.7	56.3	76.0	84.5	87.5
		sans produit	0.0	5.0	6.9	9.9	16.7	19.6	21.5
N minéralisé (+) ou immobilisé (-)	% d'azote organique du produit		0.0	6.3	14.7	20.2	25.8	28.2	28.8

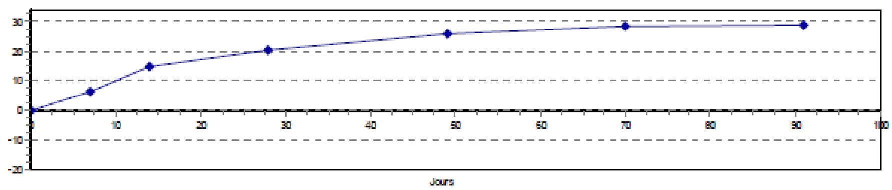
Quantité d'azote minéral présent dans le sol sous forme NH_4 et NO_3



Minéralisation nette de l'azote organique en azote minéral (NO_3 + NH_4)



N minéralisé (+) ou immobilié (-) en % de N organique du produit



AUREA - 270 Allée de la Pomme de Pin, 45160 Ardon Tél. 01.44.31.40.40 - Fax. 01.44.31.40.41

A.2.2- C mineralisation for the batch tested in field trial in 2019

aurea AgroSciences

ANALYSE RÉALISÉE POUR :	ORGANISME :
RENUFARM 2018	ARVALIS ESTREES MONS DOMAINE INRA 80200 ESTREES-MONS

N° de laboratoire	Référence échantillon		Dates repères	
11816672	Référence :	LIPO70	Date de prélèvement :	
	Commune :		Date de réception :	22/03/2019
	Station :		Date de sortie :	05/08/2019

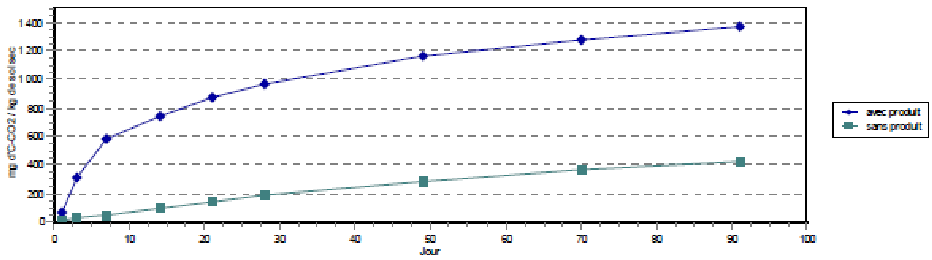
Échantillon analysé :
CDE RENUFARM2018/LAMPAERT/ESTREES MONS
Type produit : AMENDEMENTS ORGANIQUES

MINÉRALISATION DU CARBONE

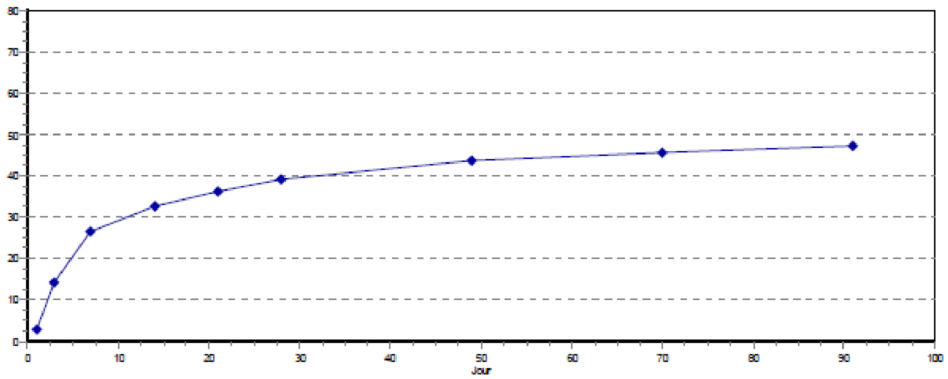
Résultats de la minéralisation du carbone

	Unité		J1	J3	J7	J14	J21	J28	J49	J70	J91
Quantité de $C-CO_2$ dégagé par le sol	mg de $C-CO_2$ / kg de sol sec	avec produit	66.5	311.5	582.4	745.3	867.5	964.5	1160.6	1275.6	1373.1
		sans produit	8.2	27.8	49.5	91.0	143.6	183.4	284.1	362.4	425.7
Coefficient de minéralisation	% de carbone organique du produit		2.9	14.2	26.6	32.7	36.2	39.1	43.8	45.7	47.4

Quantité $C-CO_2$ dégradé par le sol



Coefficient de minéralisation exprimé en % sur C organique initial du produit



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A.2.3- C mineralisation for the batch tested in field trial in 2019: measurements of ISMO

aurea AgroSciences

DEMANDEUR :	ORGANISME :
RENUFARM 2018	ARVALIS ESTREES MONS DOMAINE INRA 2 CHAUSSEE BRUNEHAUT 80200 ESTREES-MONS

N° LABORATOIRE
11816672

Dates Prélèvement	Dates Arrivée	Dates Expédition
	22/03/2019	25/06/2019

MARQUE	
RÉFÉRENCE	LIPO70
N° LOT	
N° SCELLÉ / CODE BARRE	
RÉFÉRENTIEL	
TYPE PRODUIT	AMENDEMENTS ORGANIQUES

Evaluation de la stabilité biologique

Déterminations		Méthode	Résultats
Matière sèche (1)	% du produit brut	Méthode interne selon NF EN 13040	58.5
Matière organique (2)	% de matière sèche	Méthode interne selon NF EN 13039	65.13
NDF org.	% de la matière organique partiellement sec à 40 °C (insolubles dans le détergent neutre)	FD U44-162	46.55
ADF org.	% de la matière organique partiellement sec à 40 °C (insolubles dans le détergent acide)	FD U44-162	31.80
ADL org.	% de la matière organique partiellement sec à 40 °C (lignine sulfurique)	FD U44-162	11.31
* Composés organiques solubles (SOL)	% de la matière organique partiellement sec à 40 °C	FD U44-162	53.45
* Hemicelluloses (HEM)	% de la matière organique partiellement sec à 40 °C	FD U44-162	14.74
* Cellulose (CEL)	% de la matière organique partiellement sec à 40 °C	FD U44-162	20.49
* Lignines et cutines (LIC)	% de la matière organique partiellement sec à 40 °C	FD U44-162	11.31
Cellulose brute Weende (CEW)	% de la matière organique partiellement sec à 40 °C	XP U44-162	27.09
Carbone organique minéralisé à 3 jours	% du carbone organique	FD U44-163	14.19

ISB - Indice de Stabilité Biochimique	proportion de la matière organique	0.18
ISMO - Indice de Stabilité de la Matière Organique (3)	% de la matière organique	42.4
	kg de MO stable / t de matière sèche	276
	kg de MO stable / t de matière brute	162

Commentaire

1 tonne de produit brut pourrait fournir 162 kg de matière organique potentiellement résistante à la dégradation(calcul avec ISMO).

Kg MO potentiellement résistante à la dégradation = (1) x 10 x (2) / 100 x (3) / 100

A.2.4- C mineralisation for the batch tested in field trial in 2020: measurements of ISMO

aurea AgroSciences

DEMANDEUR :
CDE 5430-90-77150

ORGANISME :
ARVALIS BAZIEGE
6 CHEMIN DE LA COTE VIEILLE
31450 BAZIEGE

N° LABORATOIRE		
2202175		
Dates		
Prélèvement	Arrivée	Expédition
	04/03/2020	24/03/2020

MARQUE	
RÉFÉRENCE	28 RENU2FARM-COMPOST 1-1.6-0.7 (LIPO 70)
N° LOT	
N° SCELLÉ / CODE BARRE	
RÉFÉRENTIEL	
TYPE PRODUIT	AMENDEMENTS ORGANIQUES

Evaluation de la stabilité biologique

Déterminations		Méthode	Résultats
Matière sèche (1)	% du produit brut	Méthode interne selon NF EN 13040	32.2
Matière organique (2)	% de matière sèche	Méthode interne selon NF EN 13039	67.73
NDF org.	% de la matière organique partiellement sec à 40 °C (insolubles dans le détergent neutre)	FD U44-162	70.00
ADF org.	% de la matière organique partiellement sec à 40 °C (insolubles dans le détergent acide)	FD U44-162	49.16
ADL org.	% de la matière organique partiellement sec à 40 °C (lignine sulfurique)	FD U44-162	18.58
* Composés organiques solubles (SOL)	% de la matière organique partiellement sec à 40 °C	FD U44-162	30.00
* Hemicelluloses (HEM)	% de la matière organique partiellement sec à 40 °C	FD U44-162	20.83
* Cellulose (CEL)	% de la matière organique partiellement sec à 40 °C	FD U44-162	30.59
* Lignines et cutines (LIC)	% de la matière organique partiellement sec à 40 °C	FD U44-162	18.58
Cellulose brute Weende (CEW)	% de la matière organique partiellement sec à 40 °C	XP U44-162	38.13
Carbone organique minéralisé à 3 jours	% du carbone organique	FD U44-163	8.93

ISB - Indice de Stabilité Biochimique	proportion de la matière organique	0.32
ISMO - Indice de Stabilité de la Matière Organique (3)	% de la matière organique	45.9
	kg de MO stable / t de matière sèche	311
	kg de MO stable / t de matière brute	100

Commentaire

1 tonne de produit brut pourrait fournir 100 kg de matière organique potentiellement résistante à la dégradation(calcul avec ISMO).

Kg MO potentiellement résistante à la dégradation = (1) x 10 x (2) / 100 x (3) / 100

A3. Laboratory report for N and C mineralisation measurements for the product LiPo100

A.3.1- N mineralisation for the batch tested in field trial in 2019

aurea AgroSciences

ANALYSE RÉALISÉE POUR :
RENUFARM 2018

ORGANISME :
ARVALIS ESTREES MONS
DOMAINE INRA
80200 ESTREES-MONS

N° de laboratoire	Référence échantillon		Dates repères	
11816673	Référence :	LIPO100	Date de prélèvement :	
	Commune :		Date de réception :	22/03/2019
	Station :		Date de sortie :	05/08/2019

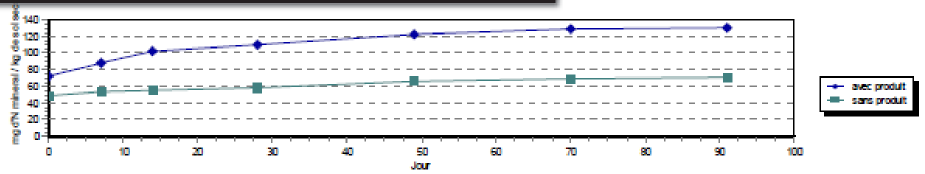
Échantillon analysé :
CDE RENUFARM2018/LAMPAERT/ESTREES MONS
Type produit : AMENDEMENTS ORGANIQUES

MINÉRALISATION DE L'AZOTE

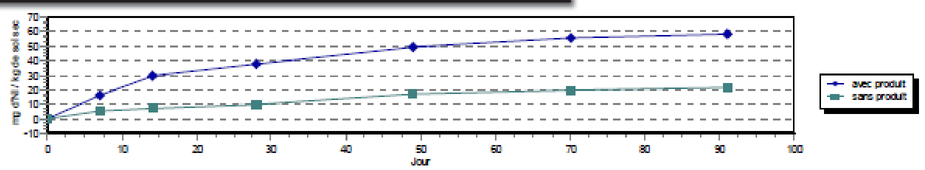
Résultats de la minéralisation de l'azote

	Unité		J0	J7	J14	J28	J49	J70	J91
Quantité d'azote minéral présent dans le sol sous forme NH_4 et NO_3	mg d'N minéral / kg de sol sec	avec produit	73.1	88.8	102.9	110.7	122.3	128.6	131.1
		sans produit	48.9	53.9	55.8	58.8	65.6	68.5	70.3
Minéralisation nette de l'azote organique en azote minéral (NO_3 + NH_4)	mg d'N minéral / kg de sol sec	avec produit	0.0	15.8	29.9	37.7	49.3	55.5	58.1
		sans produit	0.0	5.0	6.9	9.9	16.7	19.6	21.5
N minéralisé (+) ou immobilisé (-)	% d'azote organique du produit		0.0	4.7	10.1	12.2	14.4	15.8	16.2

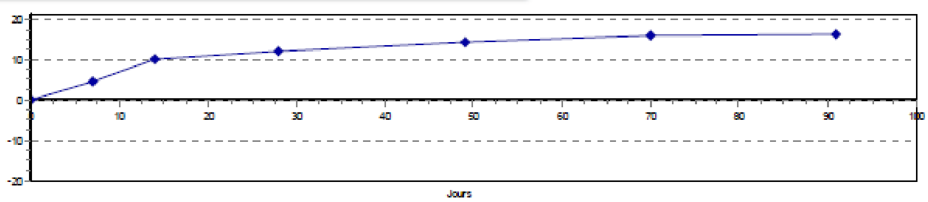
Quantité d'azote minéral présent dans le sol sous forme NH_4 et NO_3



Minéralisation nette de l'azote organique en azote minéral (NO_3 + NH_4)



N minéralisé (+) ou immobilisé (-) en % de N organique du produit



AUREA - 270 Allée de la Pomme de Pin, 45160 Ardon Tél. 01.44.31.40.40 - Fax. 01.44.31.40.41

A.3.2- C mineralisation for the batch tested in field trial in 2019

Aurea AgroSciences

ANALYSE RÉALISÉE POUR :	ORGANISME :
RENUFARM 2018	ARVALIS ESTREES MONS DOMAINE INRA 80200 ESTREES-MONS

N° de laboratoire	Référence échantillon	Dates repères
11816673	Référence : LIPO100 Commune : Station :	Date de prélèvement : Date de réception : 22/03/2019 Date de sortie : 05/08/2019

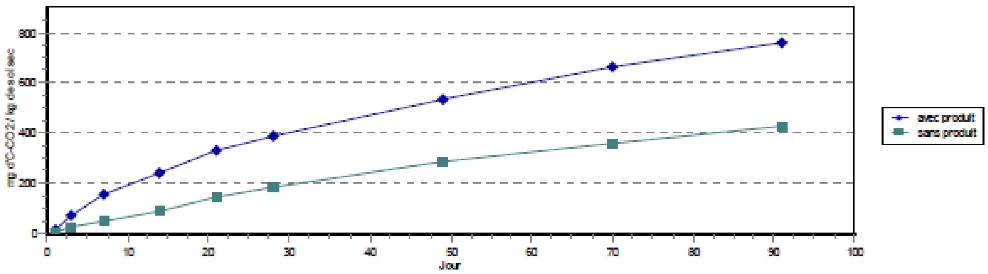
Échantillon analysé :
CDE RENUFARM2018/LAMPAERT/ESTREES MONS
Type produit : AMENDEMENTS ORGANIQUES

MINÉRALISATION DU CARBONE

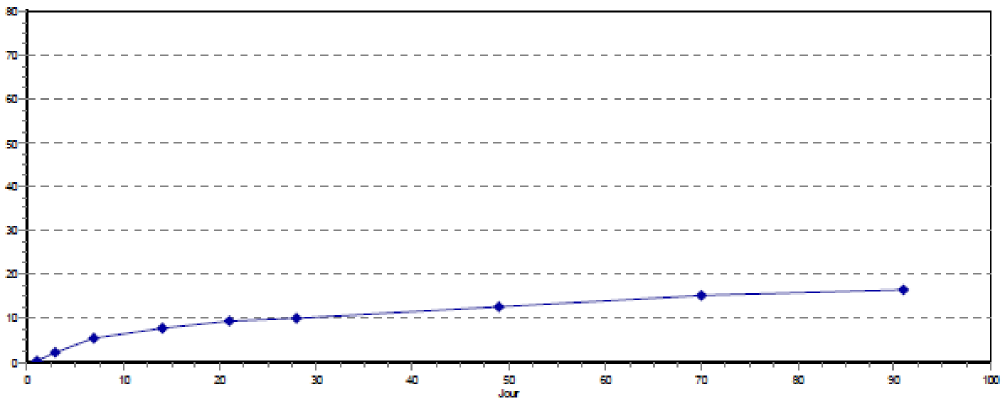
Résultats de la minéralisation du carbone

	Unité		J1	J3	J7	J14	J21	J28	J49	J70	J91
Quantité de C-CO_2 dégagé par le sol	mg de C-CO_2 / kg de sol sec	*avec produit*	16.2	71.7	159.4	243.5	329.4	386.1	536.1	665.2	758.9
		sans produit	8.2	27.8	49.5	91.0	143.6	183.4	284.1	362.4	425.7
Coefficient de minéralisation	% de carbone organique du produit		0.4	2.2	5.5	7.6	9.3	10.1	12.6	15.1	16.7

Quantité C-CO_2 dégradé par le sol



Coefficient de minéralisation exprimé en % sur C organique initial du produit



Interreg North-West Europe ReNu2Farm
European Regional Development Fund

A.3.3- C mineralisation for the batch tested in field trial in 2019: measurements of ISMO

aurea AgroSciences

DEMANDEUR :
RENUFARM 2018

ORGANISME :
ARVALIS ESTREES MONS
DOMAINE INRA
2 CHAUSSEE BRUNEHAUT
80200 ESTREES-MONS

N° LABORATOIRE
11816673

Dates		
Prélèvement	Arrivée	Expédition
	22/03/2019	25/06/2019

MARQUE	
RÉFÉRENCE	LIPO100
N° LOT	
N° SCELLÉ / CODE BARRE	
RÉFÉRENTIEL	
TYPE PRODUIT	AMENDEMENTS ORGANIQUES

Evaluation de la stabilité biologique

Déterminations		Méthode	Résultats
Matière sèche (1)	% du produit brut	Méthode interne selon NF EN 13040	48.6
Matière organique (2)	% de matière sèche	Méthode interne selon NF EN 13039	56.13
NDF org.	% de la matière organique partiellement sec à 40 °C (insolubles dans le détergent neutre)	FD U44-162	60.14
ADF org.	% de la matière organique partiellement sec à 40 °C (insolubles dans le détergent acide)	FD U44-162	49.95
ADL org.	% de la matière organique partiellement sec à 40 °C (lignine sulfurique)	FD U44-162	29.64
* Composés organiques solubles (SOL)	% de la matière organique partiellement sec à 40 °C	FD U44-162	39.86
* Hemicelluloses (HEM)	% de la matière organique partiellement sec à 40 °C	FD U44-162	10.19
* Cellulose (CEL)	% de la matière organique partiellement sec à 40 °C	FD U44-162	20.31
* Lignines et cutines (LIC)	% de la matière organique partiellement sec à 40 °C	FD U44-162	29.64
Cellulose brute Weende (CEW)	% de la matière organique partiellement sec à 40 °C	XP U44-162	36.10
Carbone organique minéralisé à 3 jours	% du carbone organique	FD U44-163	2.19

ISB - Indice de Stabilité Biochimique	proportion de la matière organique	0.52
ISMO - Indice de Stabilité de la Matière Organique (3)	% de la matière organique	76.1
	kg de MO stable / t de matière sèche	427
	kg de MO stable / t de matière brute	208

Commentaire

1 tonne de produit brut pourrait fournir 208 kg de matière organique potentiellement résistante à la dégradation(calcul avec ISMO).

Kg MO potentiellement résistante à la dégradation = (1) x 10 x (2) / 100 x (3) / 100

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A.3.4- C mineralisation for the batch tested in field trial in 2020: measurements of ISMO

aurea AgroSciences

DEMANDEUR :	ORGANISME :
CDE 5430-90-77150	ARVALIS BAZIEGE 6 CHEMIN DE LA COTE VIEILLE 31450 BAZIEGE

N° LABORATOIRE	
2202176	

Dates		
Prélèvement	Arrivée	Expédition
	04/03/2020	24/03/2020

MARQUE	
RÉFÉRENCE	28 RENU2FARM-COMPORG 1.8-3-3.1 (LIPO 100)
N° LOT	
N° SCELLÉ / CODE BARRE	
RÉFÉRENTIEL	
TYPE PRODUIT	AMENDEMENTS ORGANIQUES

Evaluation de la stabilité biologique

Déterminations		Méthode	Résultats
Matière sèche (1)	*% du produit brut*	Méthode interne selon NF EN 13040	32.4
Matière organique (2)	*% de matière sèche*	Méthode interne selon NF EN 13039	70.21
NDF org.	*% de la matière organique partiellement sec à 40 °C (insolubles dans le détergent neutre)*	FD U44-162	68.62
ADF org.	*% de la matière organique partiellement sec à 40 °C (insolubles dans le détergent acide)*	FD U44-162	58.50
ADL org.	*% de la matière organique partiellement sec à 40 °C (lignine sulfurique)*	FD U44-162	25.96
*** Composés organiques solubles (SOL)**	*% de la matière organique partiellement sec à 40 °C*	FD U44-162	31.38
*** Hemicelluloses (HEM)**	*% de la matière organique partiellement sec à 40 °C*	FD U44-162	10.12
*** Cellulose (CEL)**	*% de la matière organique partiellement sec à 40 °C*	FD U44-162	32.55
*** Lignines et cutines (LIC)**	*% de la matière organique partiellement sec à 40 °C*	FD U44-162	25.96
Cellulose brute Weende (CEW)	*% de la matière organique partiellement sec à 40 °C*	XP U44-162	42.99
Carbone organique minéralisé à 3 jours	*% du carbone organique*	FD U44-163	3.32

ISB - Indice de Stabilité Biochimique	*proportion de la matière organique*	0.51
ISMO - Indice de Stabilité de la Matière Organique (3)	*% de la matière organique*	64.2
	kg de MO stable / t de matière sèche	451
	kg de MO stable / t de matière brute	146

Commentaire

1 tonne de produit brut pourrait fournir 146 kg de matière organique potentiellement résistante à la dégradation(calcul avec ISMO).

Kg MO potentiellement résistante à la dégradation = (1) x 10 x (2) / 100 x (3) / 100