Home-made composts quality: methods of assessment and results

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Home-made compost quality :

METHODS OF ASSESSMENT AND RESULTS

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Pour mieux affirmer
ses missions,
le Cemagref
devient Irstea

Sommaire

Introduction

Home-composting is a way to divert domestic organic waste from collection, but the main interest of this biological treatment is to recycle organic matter in a valuable product that can return to soil. In this objective, compost quality must concern three main aspects:

- organic amendment properties: addition of organic amendments has been proven useful to restore the quality of degraded soil that can limit agricultural productivity [1]. A soil amendment is a material added to soil that will improve its physical properties, such as water retention, permeability, water infiltration, aeration or structure. The goal is to provide a better environment for roots and thus enhance the plant development.

- Fertilizing effect: fertilizers are applied on soil to promote plant nutrition thanks to the provision of macronutrients (nitrogen, phosphorus and potassium) and other micronutrients. The major goal of fertilizer is thus to improve soil fertility and production yield of crop cultivation.

- Innocuousness: the safe use of organic wastes on land depends on several factors including its potential impacts on general environment (soils, water resources, air…) and possible impacts on animal and human health (infections for compost handlers and users, odour issues…). Using organic residues on agricultural land can bring environmental impacts such as groundwater pollution or harmful gaseous emissions. These later issues will not be properly discussed in this paper. They can be related to parameters presented here but they are predominantly influenced by the dose used on land and the period of application.

Few data on the home made compost quality can be found. Moreover, there is a large demand of user for methods to assess the development and the quality of their composts.

Thus this work had three objectives :

- To sample a large sample of home made composts to obtain a data base of compost quality (physico-chemical prameters) ;
- To compare the quality of the sampled composts to standards and guidelines given for industrial composts ;
- To ask users on their own assessment of their composts through the use of organoleptic parameters and to compare with the analysed quality.

At the end of the document, the main information to be transfered to waste and prevention community services and to users is summarised.

Materials and methods

Physico-chemical assessment

Sampling panel

Along this experiment we chose to sample composts on the basis of three parameters:

- Composts must be aged of more than 5 months (considered as the minimal time required to obtain a usable compost).
- The season : end of autumn and end of spring
- The type of housing/composting : individual housing and composting versus collective housing or composting

In order to have a good statistical analysis of the results we chose to work on a total panel of 60 samples:

- 40 for individual housing: 15 end of autumn; 25 end of spring
- 20 for collective housing: 5 end of autumn; 15 and of spring

The sampling panel for individual composting was based on volunteering. Firstly the volunteers from the study of the quantitative impact of home-composting were asked. Only about half of them answered and agreed to be part of the study on compost quality. Then, a call for volunteers was emailed among the Rennes Metropole staff. Finally only 39 individual composts were sampled (only 14 at the end of spring).

The sampling panel for collective housing/composting was chosen with the Rennes Metropole waste prevention service and their provider for the maintenance of collective composting site.

Method of sampling

In order to sample the most mature compost, samples were taken in the bottom third of the compost heap or composting bin (Figure 1). To do so, in case of a composting bin, a side was opened to sample. In case of a pile, the upper part of the compost was discarded in order to **sample the most mature zone**.

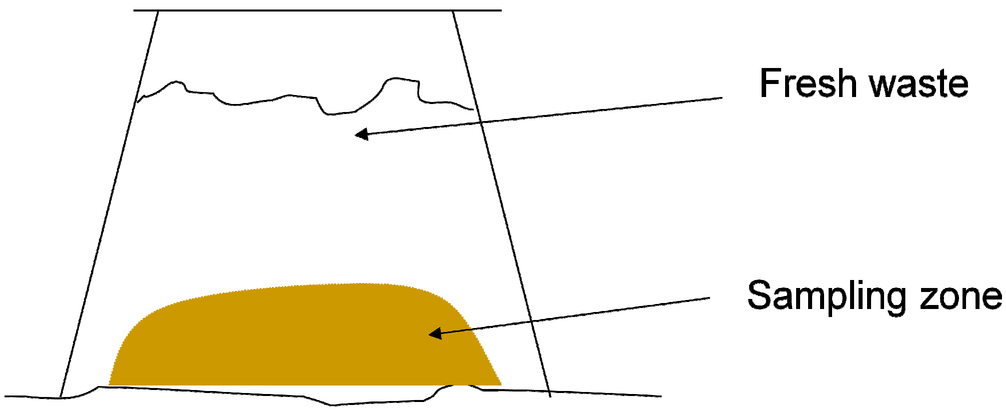

Figure 1 : Sampling zone in a composting bin or compost pile

Around 3 kg of compost were sampled (for a 300 l bin): 2.5kg for physico-chemical analysis and 0.5kg for bacterial analysis.

Characterization parameters and methods

The samples were analysed regarding the following criteria:

Chemical and biochemical criteria

- Dry matter content
- Organic matter content
- Total chemical oxygen content
- Total carbon content
- Total Nitrogen content
- Soluble Chemical oxygen demand
- Soluble carbon content
- Soluble Kjeldhal nitrogen content (Kjeldhal nitrogen equals to the sum of organic nitrogen and ammonium)
- Nitrates
- pH
- Fibres: Soluble fraction, Hemicellulosic fraction, cellulosic fraction, lignin (% of OM)

Fertilizing parameters

- Total Nitrogen (% of WM)
- Potassium (K_2O % of WM)
- Phosphorus (P_2O_5 % of WM)

Innocuousness parameters

- Heavy metals: Cadmium, Chrome, Copper, Nickel, Zinc, Mercury, Lead, Selenium, Arsenic (mg/ kg DM)
- Organic pollutants : Benzo(a)pyrene, Benzo(b)fluoranthène, Fluoranthène (mg/kg DM)

Phytotoxicity parameter

- Germination Index (GI): germination of cress seeds and ray-grass on composts aqueous extracts.

These parameters were chosen following the specifications of French standard for soil improvers. Some parameters were added to better know the chemical and agronomic quality of the sampled composts.

Statistical tests have been performed to compare results on the basis of the sampling season and type of composting (individual or collective): comparison of means (Student tests). Moreover relations have been searched between parameters: Analysis of Variance.

Organoleptic assessment

At the occasion of each sampling, a form with different choice for sensory parameters was filled with the compost makers. These volunteers had also the possibility to add commentaries on the quality of their compost but also on the assessment form: adequacy of the used terms, other ways to state on the quality of their compost.

Assessment criteria

First page of the form concerned general information: name and address, type of composting, Age of compost or date of the last total mixing, date of sampling, weather.

On the second page the assessment began by the observation of living forms in or around the compost near the sampling point. Then the colour and the level of homogeneity of the compost at the sampling point were asked.

On the third page, the questions concerned the temperature, the odour (proposed odours are based on the odour wheel methodology [2]) and the texture of the sample. Lastly on the fourth page came the fist test and the opened questions.

Survey form

Survey form is presented on annex 1.

Results

Typology of the samples

Sampling panels are characterized by the type of housing, the type of composting performed and the age of the compost sampled.

As it was sometimes difficult to know the exact age of beginning of the compost, three categories were proposed: less than one year (remind that all composts are older than 5 months); between 1 and 2 years; more than 2 years.

Type of composting was also divided in three categories: composting in wood bin, composting in plastic bin and pile composting.

Individual compost

Around 75% of the composts sampled in individual housing were younger than 2 years (Figure 2), equally distributed between less than one year composts and one to 2 years composts. 22 % of the composts sampled were more than 2 years old. It corresponds to volunteers that made compost to divert waste from the general collection but that don't use the obtained composts.

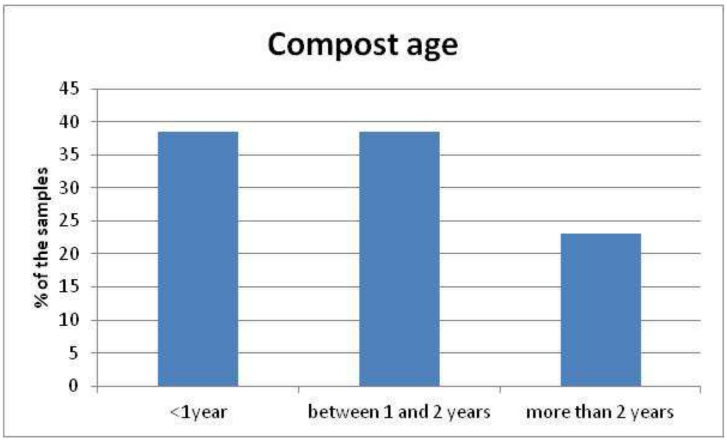

Figure 2: Age distribution of individual composts

Most of the volunteers (around 46 %) used plastic composting bin. Around 38 % preferred wood bin. Only 15 % practised pile composting. Such a low representation of pile composting may probably be explained by the fact that most of the volunteers lived in urban or suburban area, where pile composting is not as convenient as bin composting. (Note that the Ademe survey (2008)[3] showed that in rural area the proportion of pile composting reached 64 %.)

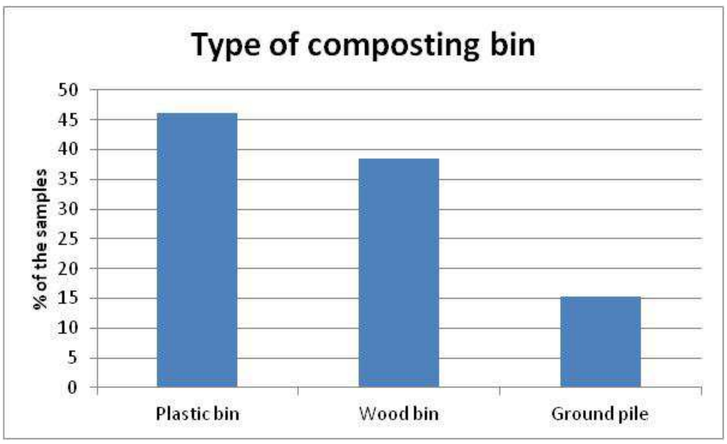

Figure 3: Distribution of the type of composting within the individual panel.

Collective compost

Home composting in collective housing was always performed in wood bin. It is a choice made by Rennes Metropole. Collective composts, that were sampled, were quite equally distributed between compost younger than one year (and generally around 6 months) and composts elder than one year (and generally less than 18 months) (Figure 4). Depending on the composting site, there was on or two composting bin: one for waste feeding and one without waste feeding for maturation. In this last case, the sampling was made in the maturation bin.

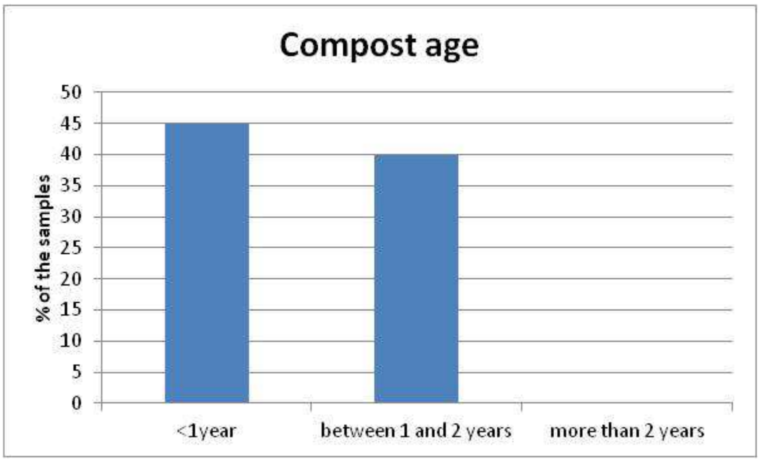

Figure 4: Age distribution of individual composts

Physico-chemical and biochemical quality

Results on compost quality are presented below. For each parameter, the global mean is firstly presented. Then, respectively for composts in individual housing and composts in collective housing, the results are presented as follows: the global mean per type of housing, the mean for winter samples and the mean for spring samples.

General results

	General Mean	Individual Mean	Winter individual Mean	Spring Individual Mean	Collective Mean	Winter collective Mean	Spring Collective Mean
Dry Matter (%)	34,3	34,3	35,4	33,7	34,4	35,1	34,9
Organic Matter (%DM)	52,0	46,8	47,0	46,7	62,1	63,3	63,6
Organic Matter (%WM)	16,0	15,0	15,5	14,7	21,4	22,1	22,4
COD total (mg O2/g DM)	754,9	666,9	671,1	664,6	926,7	942,6	967,0
Total carbon (mg/g DM)	290,9	264,8	262,3	266,1	341,9	346,7	352,2
Total nitrogen (mg/g DM)	21,4	20,2	18,4	21,2	23,8	24,0	23,6
C/N	14,1	13,7	14,6	13,2	15,0	15,2	15,9
Soluble COD (mgO2/gDM)	28,8	22,0	13,5	25,4	40,6	42,0	39,0
Soluble carbon (mg/gDM)	10,8	8,4	3,6	10,3	27,0	21,4	15,9
Soluble inorganic carbon (mg/gDM)	1,2	1,2	0,6	1,4	1,2	1,2	1,2
Soluble Kjeldhal nitrogen (mg/gDM)	2,0	1,6	0,7	1,9	2,7	2,8	2,2
Nitrates (mg/g DM)	0,8	0,8	1,0	0,7	1,0	1,0	
pH	8,1	8,1	7,9	8,2	8,1	8,1	8,2

Table 1: Chemical characteristics of sampled composts.

Home-made composts are slightly basic. Dry matter content is above 30% with rather low organic matter content on the basis of wet mass (16%). However one must note that organic matter content on the dry basis is significantly higher for collective compost than for individual composts (Figure 5). This can be explained by the fact that collective composts are globally younger and thus less biodegraded. Moreover in individual compost, more mineral substrates as animal litter or used soils are put in the composting bin.

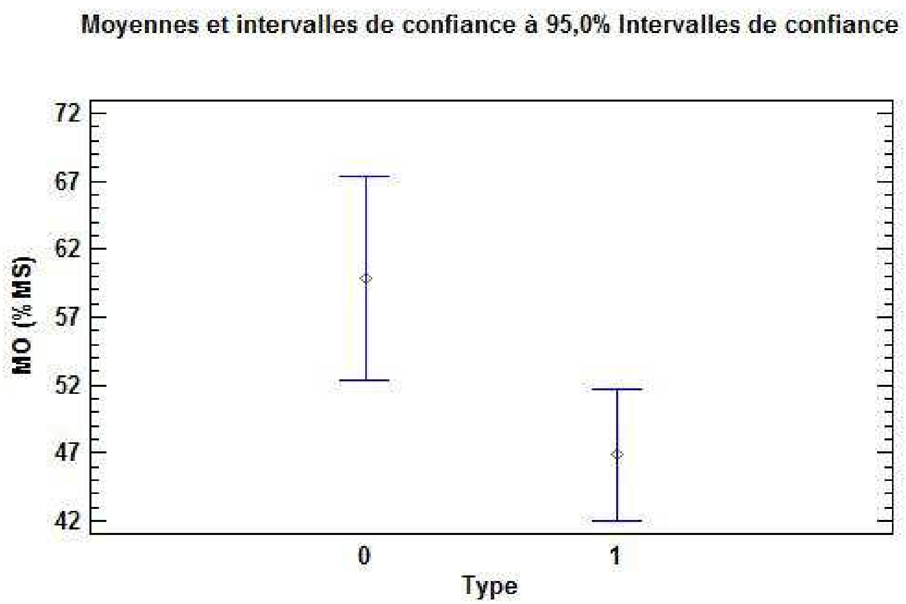

Figure 5: Comparison of mean of organic matter for collective (type 0) and individual compost (type 2)

Concerning other global chemical characteristics (Table 1), quality does not really differ depending on the type of composting (individual or collective) and on the season (winter and spring). Total carbon to nitrogen ratio is around 15, that is to say a good level for agronomic use.

Among individual composts, soluble carbon and nitrogen content significantly differ between spring and winter. Soluble carbon and nitrogen (respectively 3 and 12 % of total carbon and nitrogen content) are higher for spring compost. Substrates as grass cut may supply more biodegradable organic matter and nutrient when added in the composting bin in spring. As soluble nitrogen is the most available for plants, spring composts will bring more fertilizing elements to the soil (Figure 6).

Soluble contents also differ between individual and collective composts, whatever the season. The higher soluble contents in collective composts (especially concerning carbon content) confirm that they are more biodegradable than individual composts.

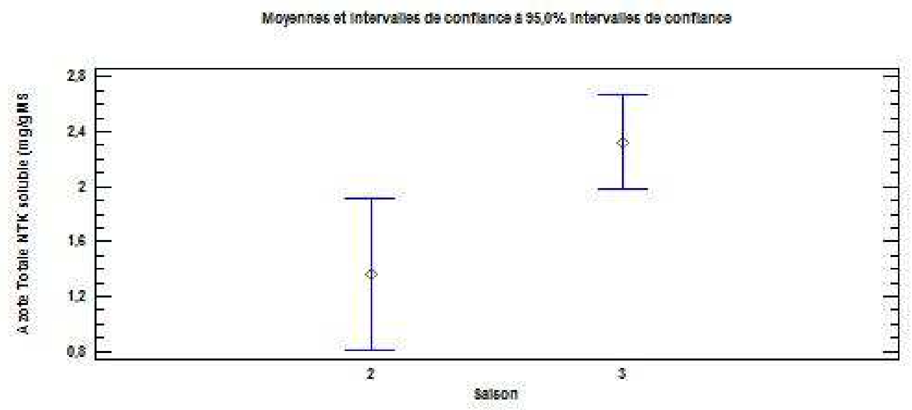

Figure 6: Comparison of mean soluble nitrogen for winter individual composts (2) and spring individual compost (3)

Biochemical characteristics

	General Mean	Individual Mean	Winter individual Mean	Spring Individual Mean	Collective Mean	Winter collective Mean	Spring Collective Mean
Soluble fraction (%DM)	23,3	25,3	26,5	24,7	19,4	22,6	18,4
Hemicellulosic fraction (%DM)	12,9	10,0	9,4	10,4	18,4	14,8	19,6
Cellulosic (%DM)	5,7	3,6	3,6	3,6	9,7	7,1	10,5
Lignin (%DM)	8,2	6,5	6,0	6,7	11,6	9,1	12,5

Table 2: biochemical fractions of compost organic matter (Van Soest or fibers fractionation)

As already noted, the collective home-made composts contained more organic matter than the individual home-made composts. Distribution between biochemical fractions differs between the two types of composts. The distribution of biochemical fractions is difficult to interpret without the additional knowledge of carbon mineralization kinetics of the two types of composts.

Fertilizing elements

	General Mean	Individual Mean	Winter individual Mean	Spring Individual Mean	Collective Mean	Winter collective Mean	Spring Collective Mean
Total Nitrogen (% WM)	0,7	0,6	0,6	0,7	0,8	0,8	0,8
Potassium (en K2O) (% WM)	0,8	0,7	0,7	0,7	0,9	0,9	0,9
Phosphorus (en P2O5) (% WM)	0,4	0,4	0,4	0,4	0,4	0,5	0,5

Table 3: fertilizing content in home-made composts

No significant difference can be observed among total fertilizing contents of home-made composts whatever the season or the type of composting, even if we have already noted that soluble nitrogen is higher for collective composts than individual composts. Total nitrogen, potassium and phosphorus content are lower than 1%. Such concentration are too low to enter the specification of fertilizers regarding the French standard NFU 42001 [4]. It does not mean that home-made composts have no fertilizing effect. It just means that they are firstly soil improvers and growing medium.

Undesirable elements

	General Mean	Individual Mean	Winter individual Mean	Spring Individual Mean	Collective Mean	Winter collective Mean	Spring Collective Mean
Cadmium (mg/kg DM)	1,7	1,5	0,6	2,0	2,1	2,2	2,1
Chrome (mg/kg DM)	18,4	12,3	11,7	12,7	30,9	8,9	38,7
Cupper (mg/kg DM)	81,2	82,9	131,8	55,5	77,6	44,0	89,6
Cupper (mg/kg OM)	174,2	193,0	311,6	126,7	69,3	79,4	44,1
Nickel (mg/kg DM)	11,9	13,2	13,2	13,2	9,1	7,6	9,7
Zinc (mg/kg DM)	179,5	188,4	155,4	206,9	161,3	82,8	189,3
Zinc (mg/kg OM)	453,2	493,0	396,2	547,1	231,4	154,5	423,7
Mercury (mg/kg DM)	1,5	1,2	2,3	0,7	2,1	1,8	2,1
Lead (mg/kg DM)	16,9	17,6	17,1	17,8	15,5	6,3	18,8
Selenium (mg/kg DM)	3,5	3,4	3,2	3,4	3,7	3,8	3,6
Arsenic (mg/kg DM)	9,6	4,1	4,2	4,1	20,8	3,2	27,0
Benzo(a)pyrène	0,113	0,146	0,097	0,191	0,022	0,023	0,0
Benzo(b)fluoranthène	0,101	0,143	0,129	0,153	0,024	0,027	0,0
Fluoranthène	0,103	0,128	0,111	0,139	0,043	0,048	0,1

Table 4: Heavy metals and organic pollutants content in sampled home-made composts

There is no significant difference between heavy metals content of collective and individual composts (Table 4), underlying the fact that main treated substrates are the same for both types of composting. It must be noted that in some samples of individual composts, high content of cupper or zinc have been found. It probably corresponds to yard waste that were treated with cupper or zinc-based product and metals accumulated in the compost. In one sample of collective compost, a high concentration of arsenic was measured. This composting site used sawdust as carbon additive. Arsenic is a product sometimes used in the treatment of wood and that can accumulate in sawdust.

Organic pollutants content is low in home-made composts but statistically higher for individual composts than collective composts. The analysed molecules belong to polycyclic aromatic hydrocarbons (PAH). Such molecules are potent atmospheric pollutants which are emitted during fuel and woods burning. Higher concentration in individual composts might come from the ashes often added in individual composts and not in collective ones. No analysis of pesticides was performed on these composts, but such molecules could also be found in individual composts because of the presence of yard waste in composting bins.

Sanitary quality

	Global	All individual	Winter individual	Spring Individual	All collective	Winter collective	Spring Collective
Viable Helminth eggs /1,5 g DM	4/59	3/39	1/14	2/25	1/20	1/5	0/15
Salmonella	1/59	1/39	1/14	0	0/20	0	0

Table 5: Parasites and bacterial content of sampled home-made composts (number of detected presence/total samples)

Most of home-made composts (91%) are free of bacterial or parasites contamination (Table 5). Presence of salmonella was found in one compost sample. But this result has not been confirmed by the analysis of a second sampling. Helminth eggs are known to be very difficult to eliminate and generally require high temperature to disappear. Considering that they were found only in 4 samples of home-made composts, it means that they were not initially present in the treated organic waste or that high temperature is not the only way to eliminate them as temperature don't generally reach very high level in home composting.

Phytotoxicity

	General Mean	Individual Mean	Winter individual Mean	Spring Individual Mean	Collective Mean	Winter collective Mean	Spring Collective Mean
GI Cress seeds	98,1	106,2	122,0	99,9	84,0	79,1	86,5
GI ray-grass	72,6	77,2	76,3	77,5	64,7	63,8	65,2
Mean GI	85,4	91,7	99,1	88,7	74,3	71,4	75,8

Table 6: Germination index of cress seeds and ray-grass on compost water extracts

The germination index (GI) is the ratio (expressed in percent) of seeds that germinate and grow on an aqueous extract of compost compared to seeds that germinate and grow on water. With GI under 70 %, the compost aqueous extract is considered as phytotoxic for plant growth. Above 100 %, the compost aqueous extract proves to have a direct positive effect on plant growth [5].

As shown in table 6, GI is globally higher for cress seeds than on for ray-grass seeds. Moreover, whatever the considered seeds, the GI is higher for individual compost than for collective compost. GI under 70 % were measured for collective composts. Phytotoxicity is generally related to the presence of phytotoxic molecules such as ammonia and easily biodegradable organic molecules such as volatile fatty acids. It underlines the fact that collective composts are mainly young composts, less biodegraded.

Comparison to marketable compost standards

The above table (Table 7) summarizes specifications that are proposed in standards or guidelines for marketable composts in different European countries and in Canada.

	Germany – Quality Label RAL-GZ 251 (For (a) fresh compost ; (b) mature compost ; (c) mulch compost ; (d) substrate compost)	**Great-Britain PAS 100:2005** [6] (apply to compost from source separated biowaste)	**Switzerland – Quality Guidelines for composts 2010** [7] (values given for horticultural use: (a)on field, (b) covered)	**France - NF U 44-051** [8] (Apply to soil improvers excluding those coming from wastewater treatment sludge)	**Canada - CCME Compost Quality Guidelines** [9] (compost that can be used in any type of application)	**ECN Quality assurance for compost** [10]

Dry matter (DM)	(A), (b) and (c) > 55 %	-	(a) >50 %* (b) >55%*	> 30% of total weight	-	-
Organic matter (OM)	(a) > 30 % DM (b) > 15 % DM (c) - (d) > 15 % DM	-	(a) < 50 % DM* (b) < 40 % DM*	> 20 or 25 % of total weight (depending on the raw substrate)	-	> 15 % of total weight
Decomposition degree	(a) II or III (b) IV or V (c) - (d) V	-	-	-	-	Threshold not reported
pH-value	-	-	(a) < 7.8 (b) <7.5	-	-	-
Salt content	(d) <2.5 or 5 g/l depending on the mixed component quantity	-	(a) < 20 gKCleq/kg DM (b) < 10 gKCleq/kg DM	-	-	-
Impurities	(Total glass, metal, plastic and any other non-stone fragments > 2 mm) <0.5 % DM	(Total glass, metal, plastic and any other non-stone fragments > 2 mm) <0.5 % DM of which 0.25 is plastic	Films + PSE>5mm < 0.1 % DM (Total glass, metal, plastic and any other non-stone fragments > 2 mm) < 0.5 % DM	Films + PSE>5mm < 0.3% of DM Other plastics >5 mm <0.8% of DM Glass + metals > 2mm <2 % of DM	No sharp foreign matter>3mm per 500 ml compost No more than 1 piece of foreign matter>25 mm in 500 ml	< 0.5 % of DM
Stones (> 5 mm)	< 5 % DM	<8 or 16 % of DM (depending on the grade of the compost)	As low as possible	-	-	-
Arsenic (As)	-	-	-	< 18 mg/kg DM	< 13 mg/kg DM	-
Cobalt (Co)	-	-	-	-	< 34 mg/kg DM	-
Molybdenum (Mo)	-	-	-	-	< 5 mg/kg DM	-
Selenium (Se)	-	-	-	< 12 mg/kg DM	< 2 mg/kg DM	-
Lead (Pb)	< 150 mg/kg DM	< 200 mg/kg DM	< 120 mg/kg DM	< 180 mg/kg DM	< 150 mg/kg DM	< 130 mg/kg DM
Chromium (Cr)	< 100 mg/kg DM	< 100 mg/kg DM	-	< 120 mg/kg DM	< 210 mg/kg DM	< 60 mg/kg DM
Nickel (Ni)	< 50 mg/kg DM	< 50 mg/kg DM	< 30 mg/kg DM	< 60 mg/kg DM	< 62 mg/kg DM	< 40 mg/kg DM
Zinc (Zn)	< 400 mg/kg DM	< 400 mg/kg DM	< 400 mg/kg DM	< 600 mg/kg DM < 1200 mg/kg OM	< 700 mg/kg DM	< 600 mg/kg DM

Cadmium (cd)	< 1.5 mg/kg DM	< 1.5 mg/kg DM	< 1 mg/kg DM	< 3 mg/kg DM	< 3 mg/kg DM	< 1.3 mg/kg DM
Copper (Cu)	< 100 mg/kg DM	< 200 mg/kg DM	< 100 mg/kg DM	< 300 mg/kg DM < 600 mg/kg OM	< 400 mg/kg DM	< 200 mg/kg DM
Mercury (Hg)	< 1 mg/kg DM	< 1 mg/kg DM	< 1 mg/kg DM	< 2 mg/kg DM	< 0.8 mg/kg DM	< 0.45 mg/kg DM
Grain size	(c) particle size < 5 mm = maximum 10 % of volume (d) < 25 mm and 50 % of the volume > 5 mm	-	(a) < 25 mm (b) < 15 mm	-	-	-
C/N	-	-	-	> 8	-	-
N	-	-	(a) > 10 g/kg DM* (b) > 12 g/kg DM*	< 3 % of total weight	-	-
N-NH4^{+}	-	-	(a) < 200 mg N/kg DM (b) < 40 mg N/kg DM	-	-	-
N-NO3^{-}	-	-	(a) > 80 mg N/kg DM (b) > 160 mg N/ kg DM	-	-	-
N-NO2^{-}	-	-	(a) < 20 mg N / kg DM* (b) < 10 mg N / kg DM*	-	-	-
N-NO2^{-} + N-NO3^{-} + N-NH4^{+} + N-urea	-	-	-	< 33 % of total N	-	-
N-NO3^{-} + N-NH4^{+}	(d) <300 or 600 mg/l depending on the mixed component quantity				-	-
N-NO_3^{-}/(N-NH_4^{+}+ N-NO_3^{-})	-	-	(a) > 0.4 (b) > 0.8		-	-
P_2O_5	(d) <1200 or 2400 mg/l depending on the mixed component quantity	-	-	< 3 % of total weight	-	-
K_2O	(d) <2000 or 4000 mg/l depending on	-	-	< 3 % of total weight	-	-

	the mixed component quantity					
$N + P_2O_5 + K_2O$	-	-	-	< 7% of total weight	-	-
Cl^-	(d) <500 or 1000 mg/l depending on the mixed component quantity	-	-	-	-	-
Na^+	(d) <250 or 500 mg/l depending on the mixed component quantity	-	-	-	-	-
$CaCO_3$	<10 % DM	-	-	-	-	-
Germinable seeds	As low as possible	0	-	-	-	< 2/L
Salmonella	0	0 in 25g fresh mass	-	0 in 1 g of compost (or in 25 g of compost for market gardening)	0	0 in 25 g DM
Escherichia Coli	-	< 1000 CFU / g fresh mass	-	-	-	-
Fecal coliforms	-	-	-	-	< 1000 MPN/g DM	-
Viable helminth eggs	-	-	-	Absence in 1.5 g of compost	-	-
Microbial respiration rate	-	< 16 mg CO_2 / g OM / day	-	-	< 400 mg O_2/kg OM/h or < 4 mg CO_2/kg OM/ day	-
Germination test **Cress seeds (open)** **Cress seeds (closed)** **Lettuce** **Beans** **Raygrass**	-		(a) > 50 % of the reference (b) > 75 % of the reference (a) > 25 % of the reference (b) > 50 % of the reference (a) > 50 % of the reference* (b) > 70 % of the reference (a) > 70 % of the reference* (b) > 70 % of	-	-	-

Reduction in germination of plants in amended compost **Reduction in plant mass above surface in amended compost** **Description of any visible abnormalities**		< 20 % of germinated plant in peat control <20 % of plant mass above surface in peat control No abnormalities	the reference*			
Polycyclic aromatic hydrocarbons **Fluoranthene** **Benzo(b)fluoranthene** **Benzo(a)pyrene**		-	<4 mg/kg DM	<4 mg/kg DM <2.5 mg/kgDM <1.5 mg/kgDM	-	-
Polychlorinated biphenyls, dioxine, Furane		-	20. 10^{-12} eq toxicity / kg DM	-	-	-

Table 7: Proposed standards and guidelines for composts in different countries.

For analysed chemical parameters, home-made composts are generally in line with the proposed specifications. For example, organic matter content is lower than the French specifications for soil improvers but in line with the threshold proposed by ECN.

Considering heavy metals, home-made composts fulfil strictest specifications, unless for cadmium and mercury, those are just in line with French standards.

Regarding organic pollutants, home-made composts are far under the strictest specifications for PAH.

Regarding pathogens, at a European level, mainly salmonella are analysed. Sampled composts were free of salmonella (except 1 sample that should be verified).

Thus, on conclusion, regarding the European and Canadian guidelines, **home-made composts are safe and can be used as soil improvers**. Global physico-chemical characteristics don't discriminate quality among composts on a standard point of view. Nevertheless, added analyses that were performed can discriminate the level of biodegradation between the studied composts: soluble chemical parameters and germination index.

Link between phytotoxicity and physico-chemical quality

The previous conclusion stated that home-made composts generally fulfil with soil improver standard specifications. However, we also showed that more precise parameters as soluble oxygen chemical demand, carbon and nitrogen contents differ between individual and collective composts. Moreover, germination index also differs between individual and collective composts. That last parameter is an indicator of the stage of biodegradation and of the agronomic quality of the composts. We searched a linked between phytotoxicity and soluble contents of the composts (Multiple regression) and we found that GI was statistically linked with soluble Kjeldhal nitrogen content (with a probability of 98 %) and soluble chemical oxygen demand (with a probability of 80 %) (Table 8).

Parameter	*Estimation*	*Error type*	*T*	*Probability*
CONSTANT	102,946	4,00724	25,6901	0,0000
Soluble Kjeldhal Nitrogen (mg/gMS)	-6,3376	2,66838	-2,37508	0,0216
COD soluble (mgO2/gMS)	-0,182015	0,140878	-1,292	0,2025

Table 8: Multiple regression IG = f(soluble COD and soluble NTK)

ANOVA of the regression (Table 9) shows that the model really represents the variation of GI among composts (with a probability > 99,9 %) even if it is not very well adjusted (R^2 only about 31 %%). Such a low adjustment of the predicted data to experimental data may indicate that some parameters are missing in the model. For example, salinity may influence germination and was not analysed here.

Nevertheless, **one can determine that with soluble COD under 40 mgO2/gDM and soluble Kjeldhal nitrogen below 3 mgN/gDM, composts don't show phytotoxicity limitations** (Figure 7 and 8).

Source	*Square sum*	*Dof freedom*	*Mean square*	*F*	*Probability*
Model	5968,47	2	2984,23	12,73	0,0000
Residue	11251,7	48	234,409		
Total (Corr.)	17220,1	50			

R^2 = 34,6598 %
R^2-Adjusted = 31,9373 %
Table 9: Analysis of variance IG = f(soluble COD and soluble NTK)

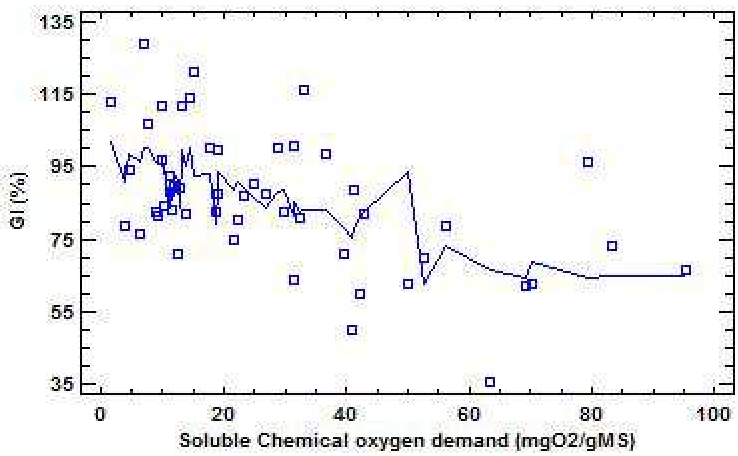

Figure 7: GI versus soluble COD

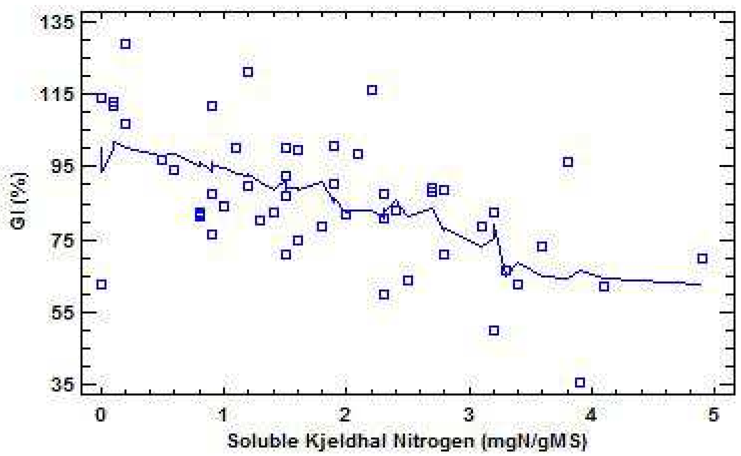

Figure 8: GI versus soluble Kjeldhal nitrogen

Organoleptic quality

Living organisms

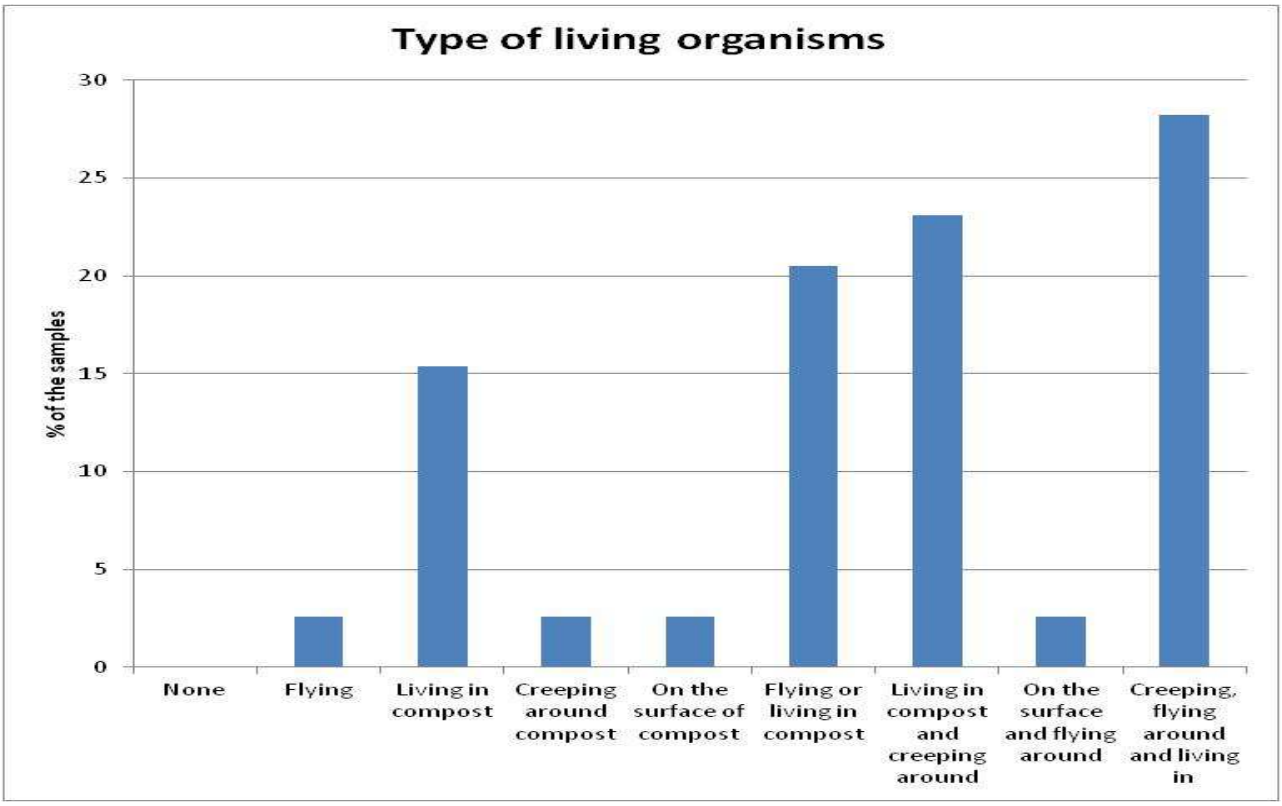

Figure 9: Type of living organisms observed in individual composts

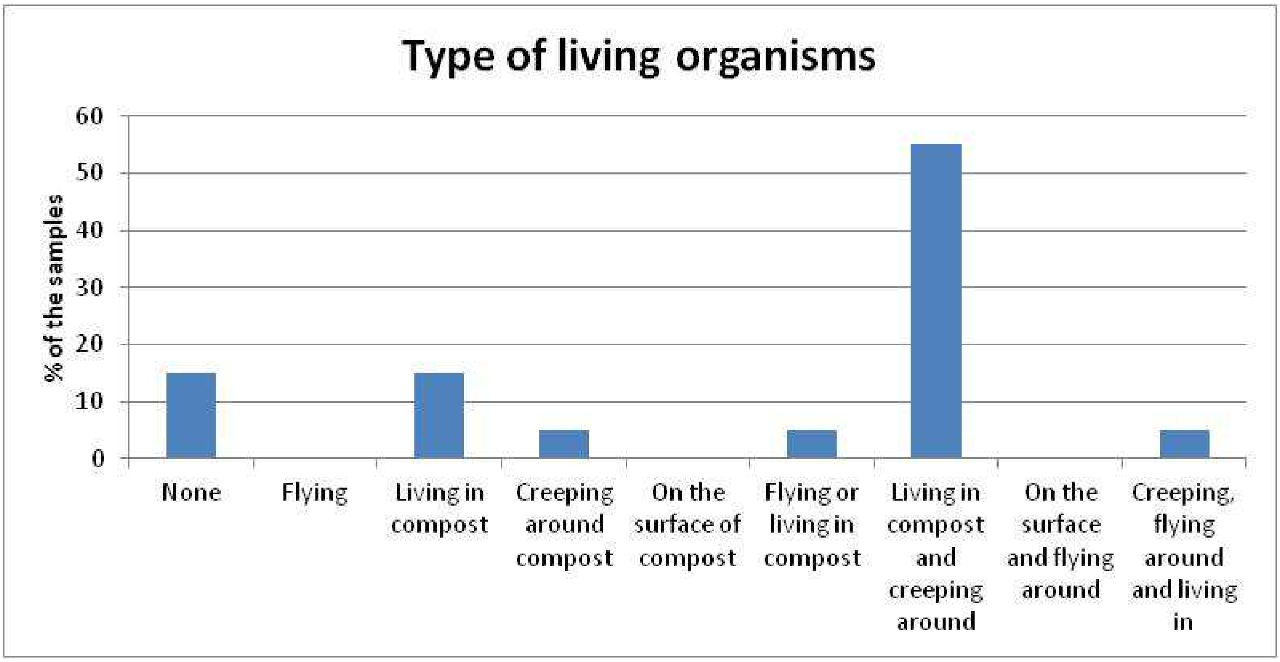

Figure 10: Type of living organisms observed in collective composts

Living organisms are easy parameters to observe. As shown on figure 9 and 10, a higher diversity of living organisms was observed in individual composts than in collective composts. Moreover, the number of observed living organisms was also higher in individual composts (Figure 11 and 12). However, the average number of observed living organisms was 3.

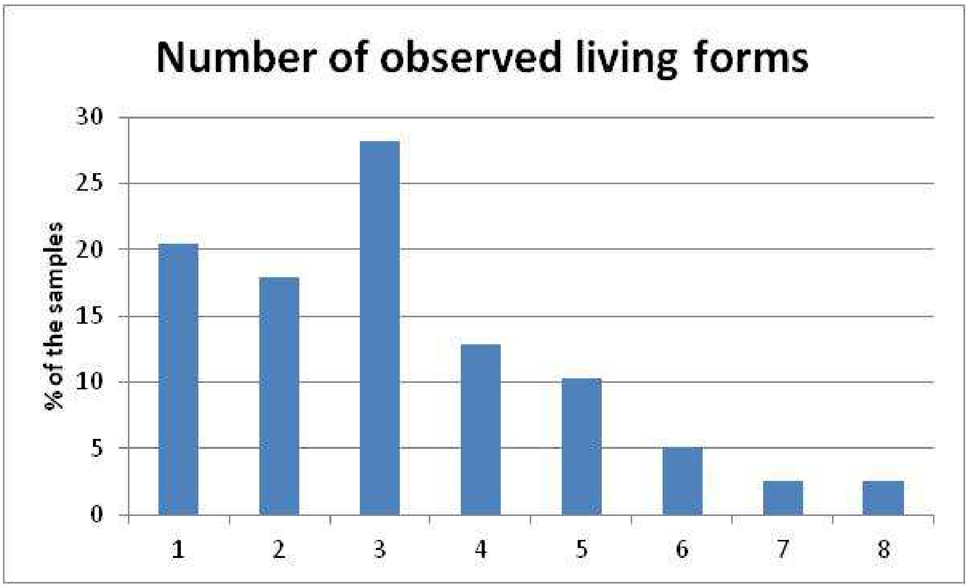

Figure 11: Number of different living organisms observed in individual composts

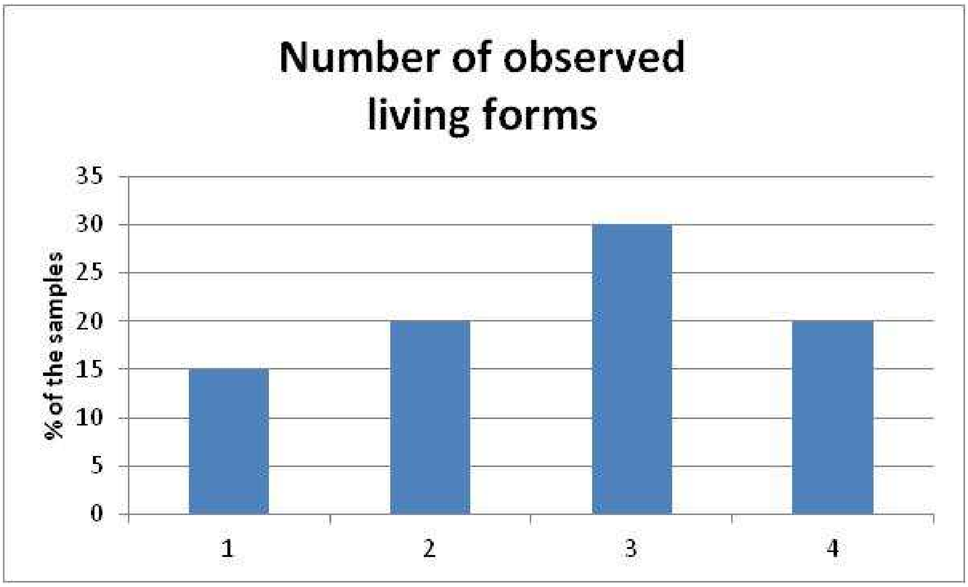

Figure 12: Number of different living organisms observed in collective composts

Colour

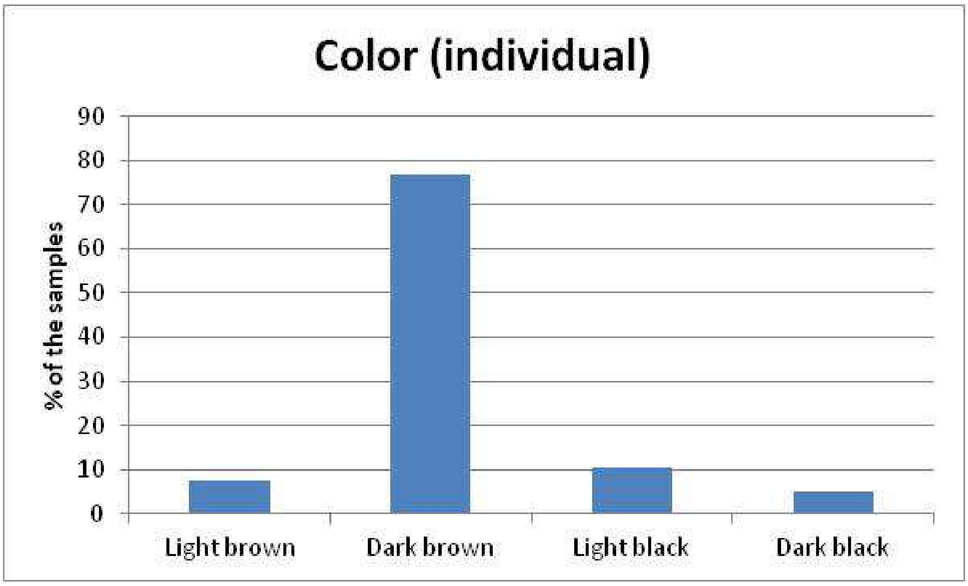

Figure 13: Colour of samples for individual composts

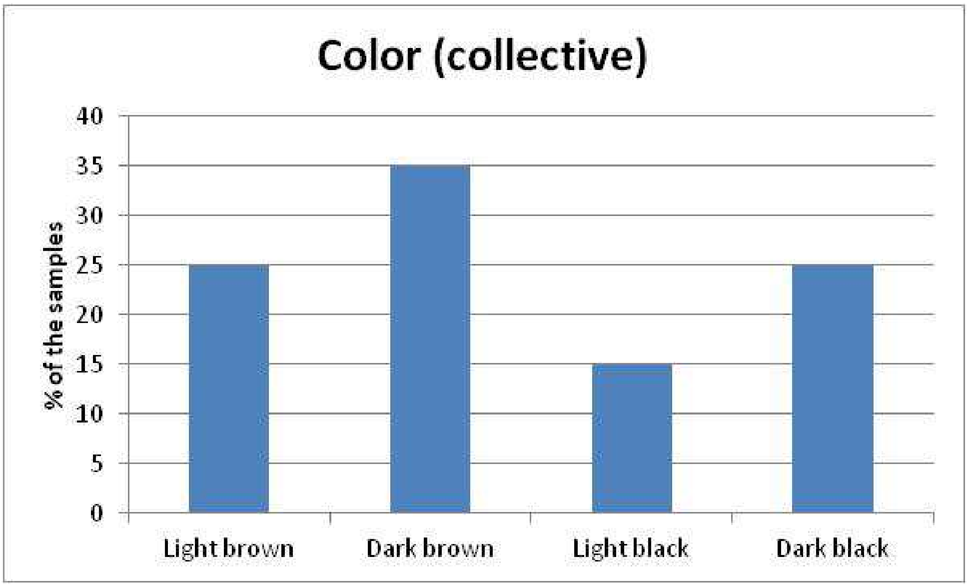

Figure 14: Colour of samples for collective composts

Colour is a sensory parameter very easy to observe. All recognized colours were distributed between light brown and dark Black. For individual composts (Figure 13), colour is not a discriminant parameter as more than 75% of samples were identified as dark brown. Collective composts are more regularly distributed between brown and black (Figure 14).

Homogeneity and texture

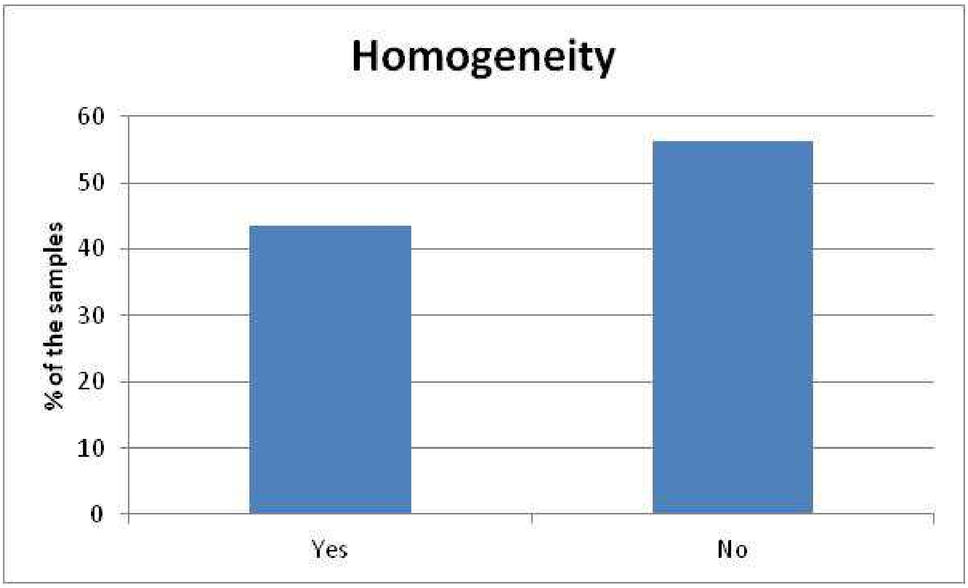

Figure 15: Homogeneity of individual composts

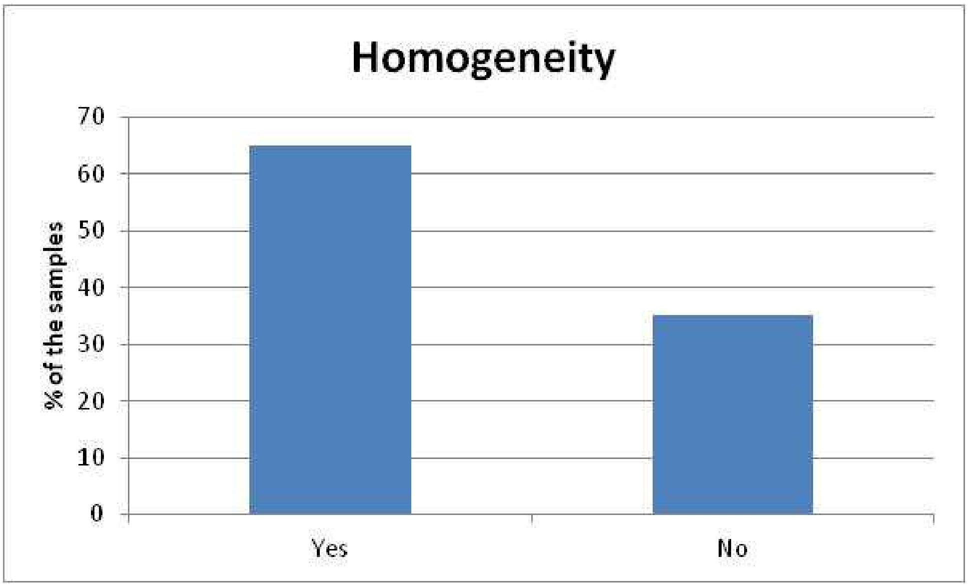

Figure 16: Homogeneity of collective composts

Homogeneity and texture are two parameters difficult to evaluate by users. As a consequence they were not reliable to discriminate composts (Figures 15 and 16).

Moisture: Fist test

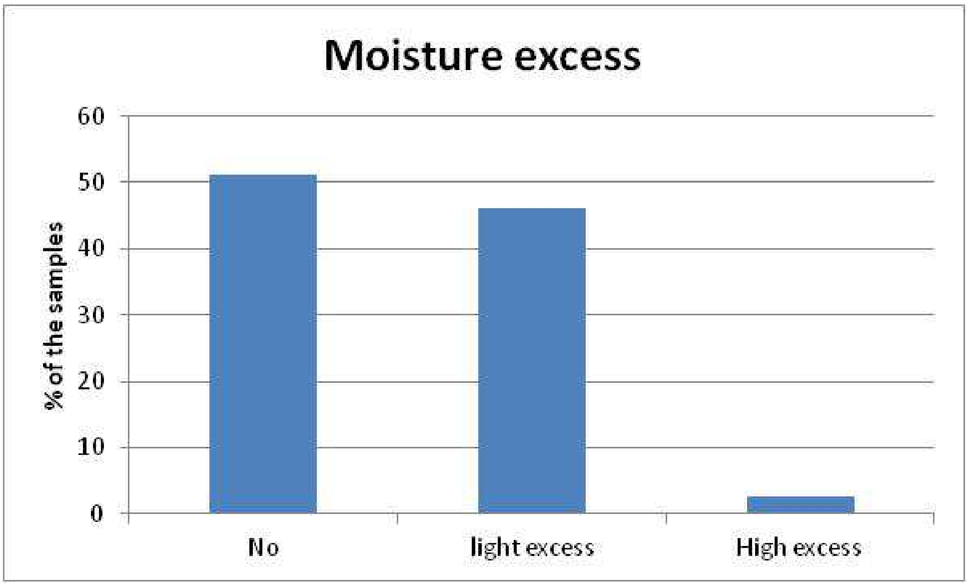

Figure 17: Fist test for individual composts

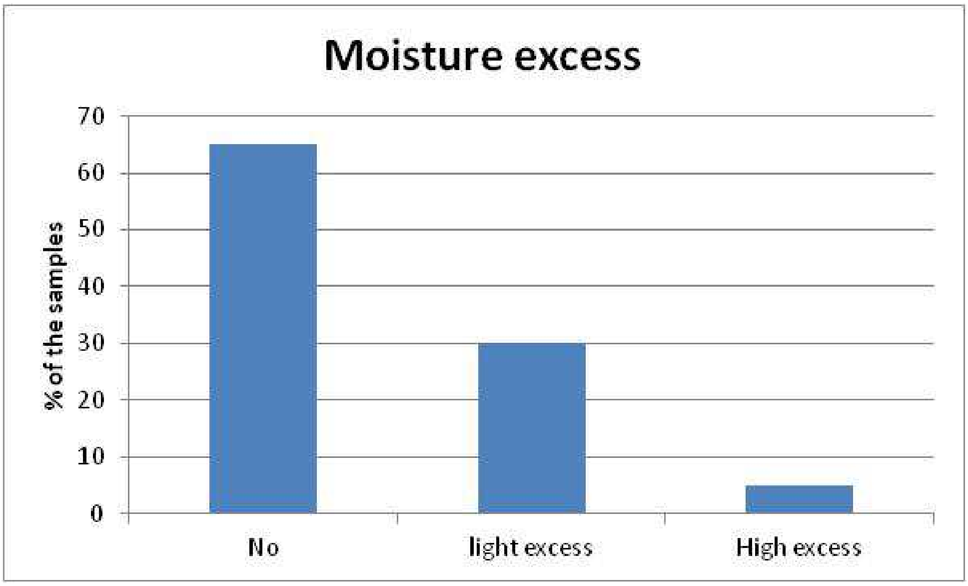

Figure 18: Fist test for collective composts

All users found that the fit test was a usable and easy to realise test. Rather no sampled composts presented an excess of water, even in winter. Main composts presented favourable moisture. Only one sample of collective compost showed a lack of moisture. Thus, even if moisture is an important parameter of composting conditions, it cannot be considered as a discriminant parameter for our study of the compost quality.

Odours

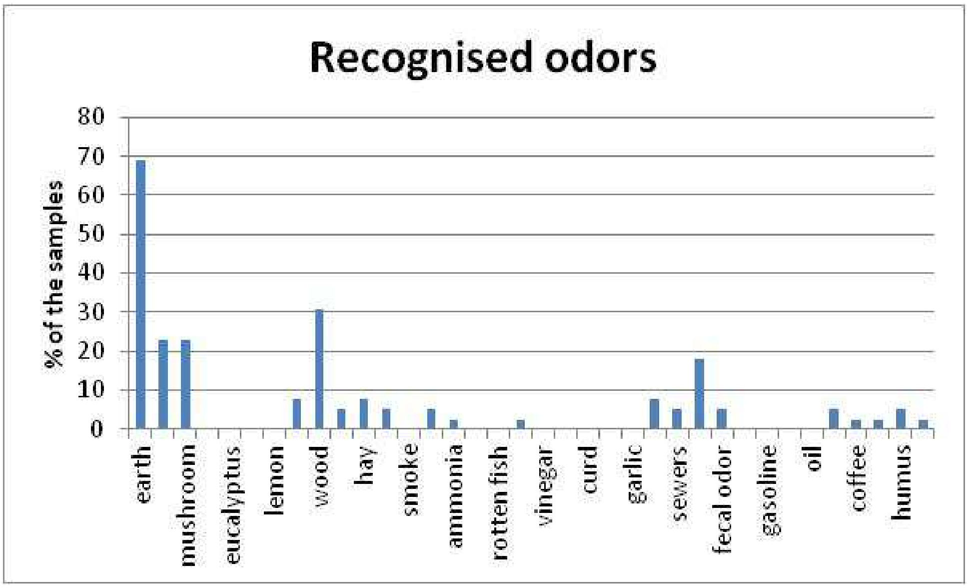

Figure 19: Recognised odours in individual composts

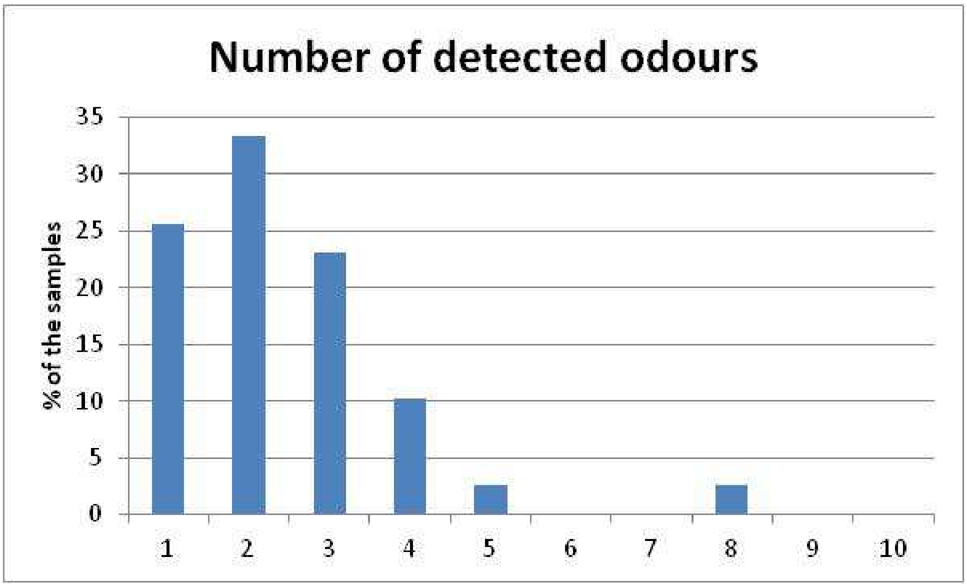

Figure 20: Number of recognised odours in individual composts

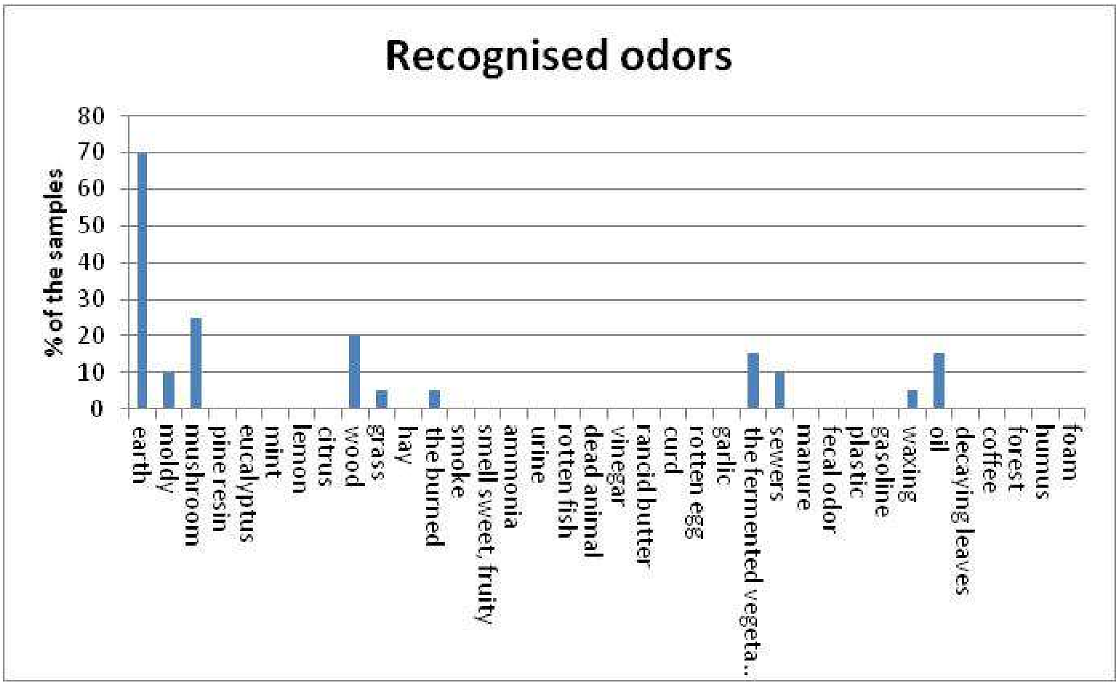

Figure 21: Recognised odours in collective composts

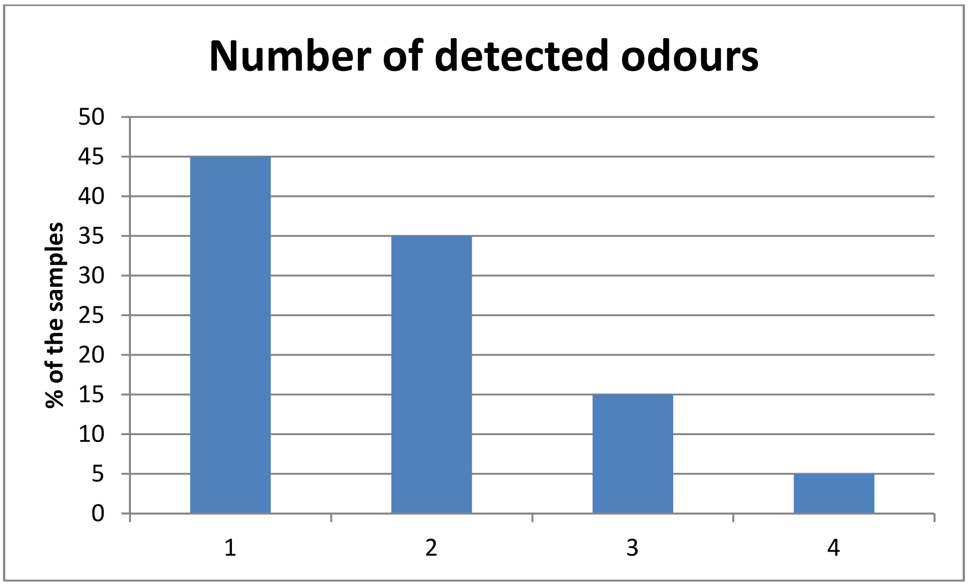

Figure 22: Number of recognised odours in collective composts

Even if users primarily feared not to recognise the proposed odours, the test was finally quite easy to perform. The degree of odour was generally low. A larger diversity of odours was recognised in individual composts (Figure 19 and 20) than in collective composts (Figure 21 and 22). 70% of the compost samples smelled an earthy odour. Bad odours (sewers, faecal odour, fermented vegetable odours) were rarely recognised. In collective composts, organic odours as solvent were recognised. Such solvent odours can be related to aldehydes and ketones emissions. These molecules are emitted in the early stage of the composting process [11]. This observation can also be linked to the age of the compost and its level of biodegradation that was proved to be lower for collective composts.

There were too much compost odour types proposed. Humus, wood, hay, fermented vegetable, sewage and solvants are probably sufficient to express the different stage of biodegradation of the biowaste.

Free remarks of users

The surveyed users found the form easy to complete and not too long.

One question to users was their personal assessment of their composts. Most users found that their composts showed good quality and were pleasant to use.

The other question was their best indicators to assess the quality of their composts. Colour and moisture were often cited. But the most cited indicator was the absence of recognisable waste.

Relation between physico-chemical and organoleptic assessment

As already noted, the average of sampled composts fulfils the quality specification imposed to marketable soil improvers. But these specifications don't discriminate the maturity of these composts and their agronomic quality.

Thus as no real difference can be observed between samples on a standard point of view, relation have been searched between the stage of biodegradation/maturity (Age and GI) and sensory parameters (colour, living forms and odours).

The index of germination is logically linked with the age of compost. As shown by Figure 23, **GI below 70 % are mainly found among young composts, under one year.**

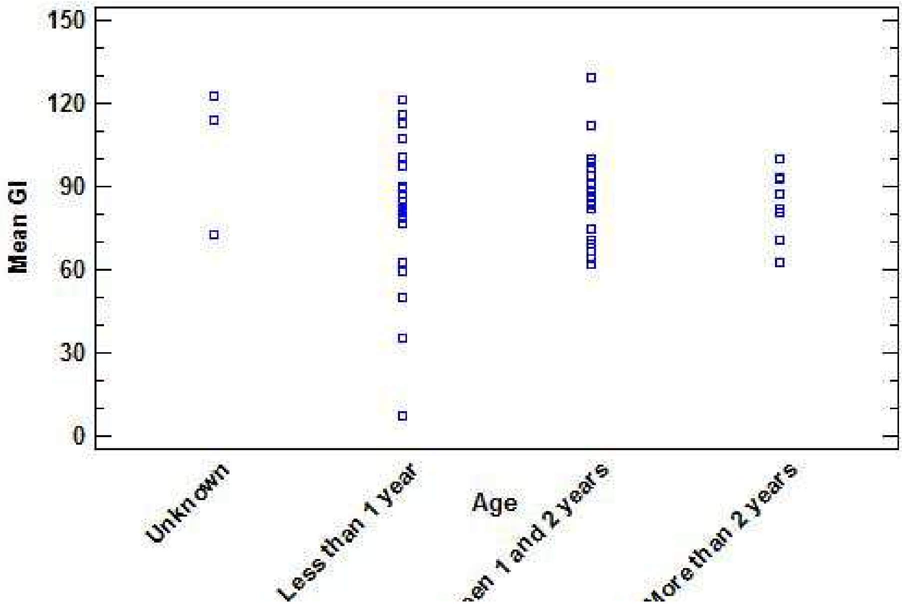

Figure 23: Linked between mean GI and compost age.

Colour is not statistically related to age or level of GI as shown by figure 24. It explains that colour was not found as discriminant parameter among composts.

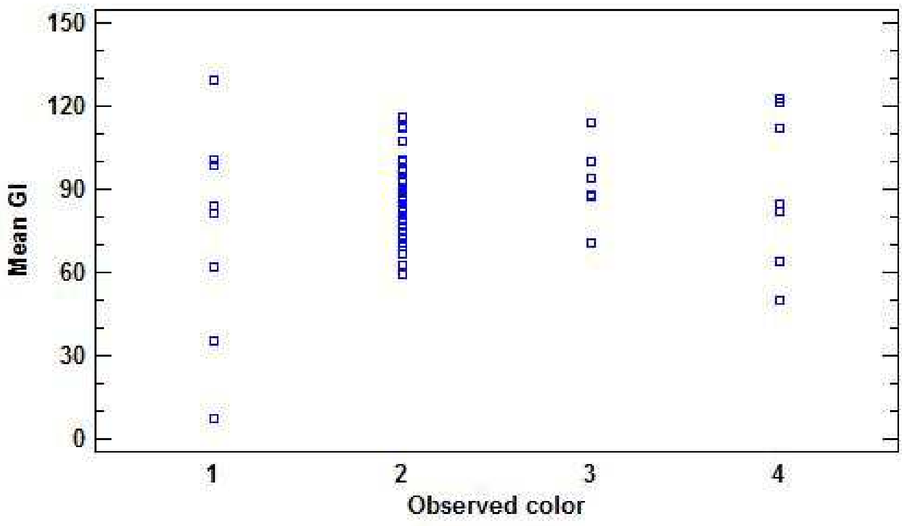

Figure 24: Linked between GI and colour of composts (1: light brown, 2:dark brown, 3: light black, 4: dark black)

Number of living forms in compost seems to be a good indicator of the evolution of the biodegradation and maturity. Indeed, when the number of living forms is low there is more chance to measure a GI below 70 % (figure 25).

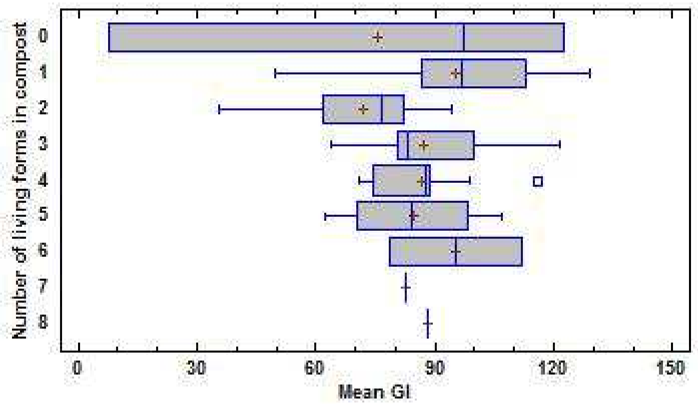

Figure 25: Linked between GI and number of living forms

Concerning odours it appears that odours decrease with the age of compost (figure 26) and that bad odours are mainly found in compost younger than 2 years (figure 27). But no real link have been found between GI and odours.

It probably means that molecules responsible of bad odours have no direct phytotoxic effect on plants.

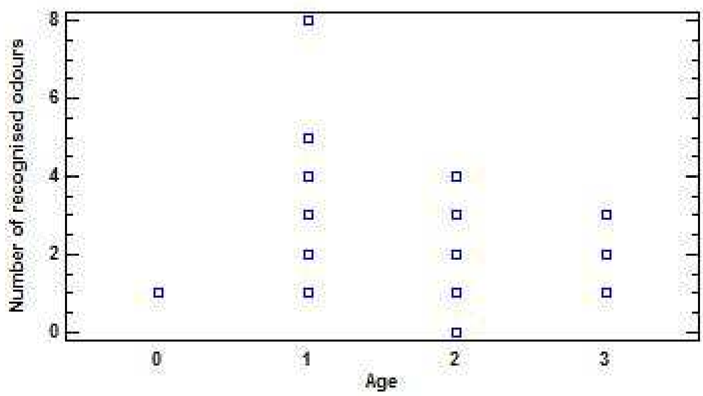

Figure 26: Link between Number of recognised odours and age (0: unknown, 1: less than one year, 2: between one and 2 years, 3: more than 2 years)

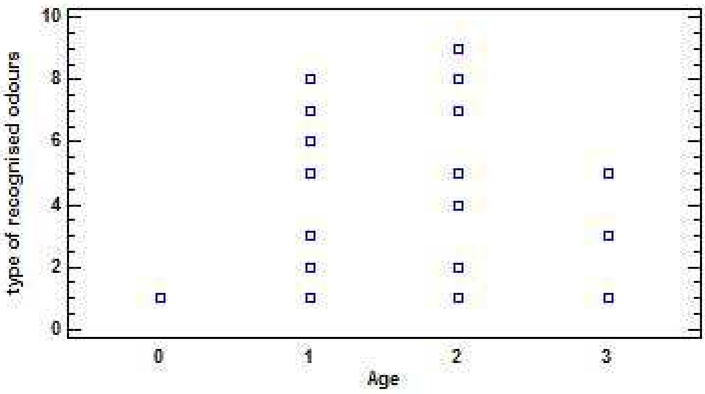

Figure 27: Link between Type of recognised odours (1: Humus, 2: Humus and grass/hay, 3: Humus and citrus, 4: Grass/hay, 5: Humus and faecal odour, 6: grass/hay, + faecal + coffee, 7: Citrus and faecal, 8: Faecal odour, 9: none) and age (0: unknown, 1: less than one year, 2: between one and 2 years, 3: more than 2 years)

On conclusion two sensory indicators discriminates the quality of composts and the level of biodegradation :

- **Living organisms are linked with the potential phytotoxicity of composts**
- **Odours are linked with the stage of biodegradation, thus the advancement of the composting treatment.**

Conclusion

The presented study followed three main objectives:

- To sample a large sample of home made composts to obtain a data base of compost quality (physico-chemical prameters) ;
- To compare the quality of the sampled composts to standards and guidelines given for industrial composts ;
- To ask users on their own assessment of their composts through the use of organoloeptic parameters and to compare with the analysed quality.

The physic-chemical analysis of the 59 compost samples demonstrated that the studied home-made composts had the following characteristics:

- Dry matter content around 30 % of wet mass
- Organic matter content around 15 % of wet mass and around 50 % of dry mass
- C/N ratio about 14
- pH about 8
- Fertilizing elements (Total N, P2O5 and K2O) less than 1 % of wet mass
- Soluble N equals 10 % of total N
- Low heavy metals content even if some punctual contamination may be measured in Copper, Zinc (probably linked to treatment made in garden and present on yard trimmings put in the composting bin)
- Parasites were rarely detected. No pathogens.
- GI test did not demonstrate strong immediate phytotoxic of composts on plant growth.

These results tend to classify home-made compost as soil improver and growing medium. They can not be defined as fertilizers.

Above results were compared with standards and guidelines for marketable composts. Mean characteristics of composts proved to be in good agreement with the specification of the ECN quality assurance for compost. Only cadmium content and mercury could be above the ECN specifications but are in line with French ones. One may also note that whatever the appearance of the sampled compost, no significant difference was measured for global parameters among samples. Standard is mainly an assurance of innocuousness of the product but not a way to evaluate the extent of biodegradation (maturity) nor the agronomic effect.

As a consequence, sensory analysis results have not been correlated with the physic-chemical characteristics of composts, but relations have been searched between sensory parameters and biodegradation extent and phytotoxic effect of composts. The conclusions are the following:

- Colour is a very easy parameter to observe. It shows when compost is pleasant to use. But Colour doesn't discriminate compost on a quality point of view. Colour is not linked with compost age or germination index.
- Moisture is an important parameter characterising the composting conditions. Nevertheless, in our study it was not a discriminant parameter as moisture conditions were good for all sampled composts.
- Presence of living forms is an encouraging parameter for the extent of biodegradation and the number of observed living forms seems to be linked with germination index.
- Odours can be easily recognised and are linked to the extent of the biodegradation: the more biodegraded the compost is, the lowest is the odour intensity (earthy odour).

These conclusions are synthesized in the compost quality assessment protocol that follows.

Synthesis: Compost quality assessment sheet

Message to disseminate about home-made compost?

Home-made composts are safe.

When home-composting classically treats biowaste (food and kitchen waste) and green waste (grass clippings, yard trimmings), composts show:

- Low heavy metals contents
- Low organic pollutants contents
- No pathogens

Home-made composts can be used on soil without fear. They fulfil the specifications of most existing standards for marketable composts

Cautions:

- If heavy metals or toxic organic compounds are used as treatment in the garden, yard waste will contain these pollutants that will accumulate in the composting bin.
- Ashes may contain PAH that will accumulate in composting bin: add only little quantities of ashes.
- Beware of animal litters added in composts that could bring faecal parasites and pathogens. If added, take care of favouring biodegradation and temperature increase in the composting bin.

Frequent asked question by users about compost quality and composting

Is the presence of living forms in my compost normal?

YES

Living forms in the compost proved that compost is not toxic and give good condition for biological life.

Is the moisture of my compost convenient?

TEST IT! Use fist test to assess if the compost moisture is convenient.

The fist test:

a. Take a handful of compost.

b. Press tight fist:

- Water trickles >> Your compost is too wet >> Bring dry materials and mix
- Droplets bead between your fingers >> compost is wet >> Be sure to mix it regularly and if possible bring some dry materials
- No perception of water >> Next Step

c. If no perception of water, continue the test by reopening your hand:

- The handle is formed, does not disintegrate >> Your compost has a favorable moisture for good degradation
- The handle breaks down your compost is too dry >> add Water

What colour must have my compost?

Compost generally have **dark brown colour**. Colour is not directly linked with agronomic quality of compost.

What is the meaning of odours in my compost?

Two types of odours might be smelled:

- Known as pleasant: earthy and Humus, Hay
- Generally known as unpleasant: fermented vegetables, ammonia, faecal odours, solvent odours

Odours are linked with biodegradation extent. Fermented vegetables and ammonia odours can corresponds to fresh waste and beginning of biodegradation. Solvent odours correspond to uncompleted biodegradation of organic matter: biodegradation is still in progress. Faecal or sewage like odours are linked to bad conditions of biodegradation: lack of aeration, excess of water

Mature compost is characterized by an earthy/humus odour. Intensity of odour decreases with the age of the compost.

Is my compost ready to use?

Compost is dark brown, moisture is convenient, odour is low and pleasant (earthy/humus), no more recognizable waste can be detected: compost is ready

How to use my compost?

Home-made composts are **soil improvers**:

- They can be used to improve soil physical properties
- They can be used as **growing medium**

Home-made compost will bring nutrients to soil but are **not formal fertilizers** as their content in N, P and K is less than 1% of wet mass (for each element)

Caution:

Young compost may contain phytotoxic molecules that severally decrease germination index. Prefer compost elder than 1 year for use as plant growing medium: phytotoxic effect is inversely related to age.

How to control compost quality?

Sampling panel constitution

The constitution of the panel largely depends on the aim of the control.

What is the question?:

- Mean general quality?
- Influence of composting practice?
- Influence of season?
- etc.

In the first case, a large volunteer call can be used.

In the other cases, a previous survey on composting habits may help to target on geographic area, specific housing, etc. when searching volunteers.

At least 20 composts per studied conditions (type of housing, composting practice…) have to be analysed to calculate reliable statistics.

To be part of the sample panel composts must be elder than 5 months.

Information to collect

When sampling compost, information has to be collected from the users:

- Type of composting (bin, pile)
- How long have they been composting?
- What are they composting?
- How are they composting (turning, adding water…)?
- Were they trained?
- Do they use their compost

How to sample

In order to **sample the most mature compost**, samples have to be taken in the bottom third of the compost heap or composting bin (Figure 1). To do so, in case of a composting bin, open a side to sample. In case of a pile, the upper part of the compost has to be discarded in order to **sample the most mature zone**.

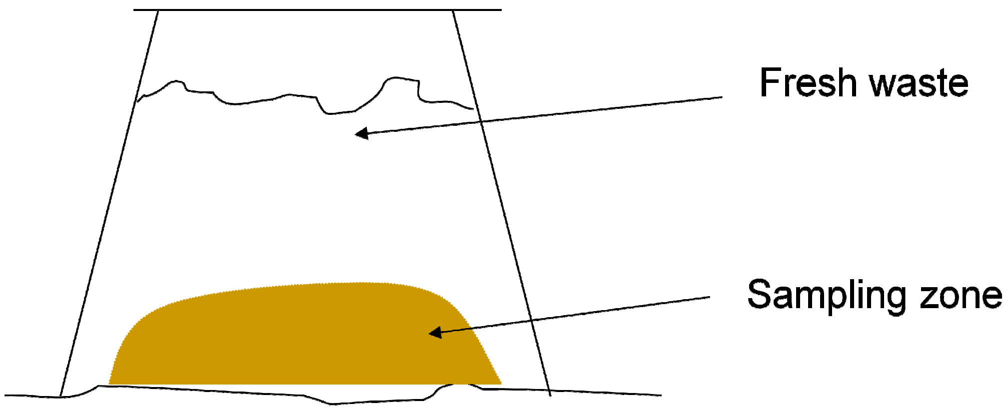

Figure 1 : Sampling zone in a composting bin or compost pile

Sample around 3 kg of compost (for a 300 l bin): 2.5kg for physico-chemical analysis and 0.5kg for bacterial analysis.

Parameters to analyse

Parameters to be analysed must include the parameters of national soil improver standard and if it doesn't exist, the parameters proposed for compost European quality assurance:

- Organic matter content
- Impurities
- Heavy metals

Lead (Pb)
Chromium (Cr)
Nickel (Ni)
Zinc (Zn)
Cadmium (cd)
Copper (Cu)
Mercury (Hg)

- Salmonella

Add some interesting agronomic parameters:

- Fertilizing content: N, P, K
- Soluble Kjeldhal nitrogen
- Ammonia nitrogen
- pH
- Salinity

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