Recalcitrant agriculture wastes to produce biogas and amendments.

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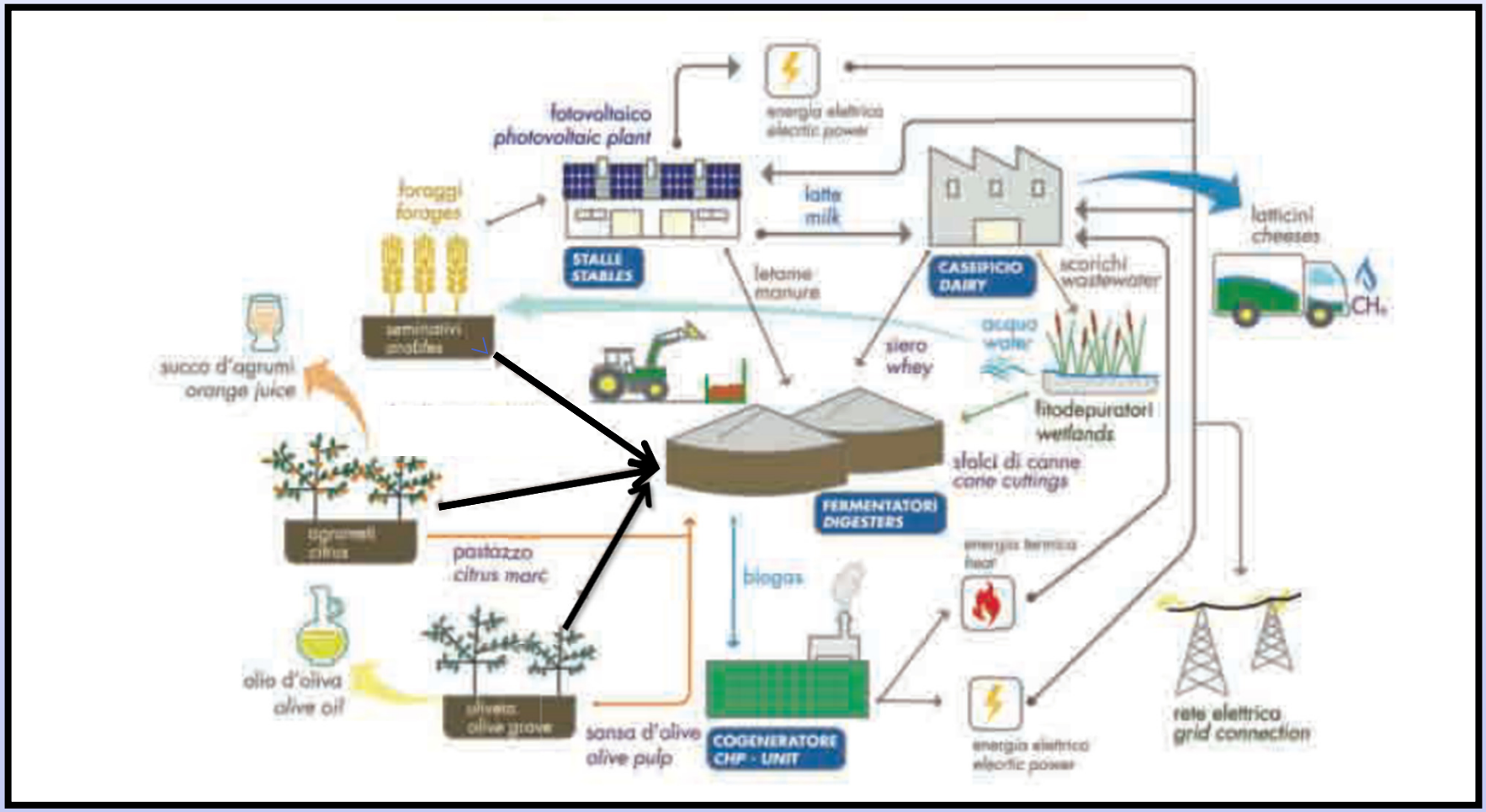
Biogas technology, is a competitive process for reducing the rate of climate change and global warming managing biodegradable waste streams to produce renewable energy in a sustainable way and a nearly stable residue (digestate).

This research is in cooperation with Fattoria della Piana owners of two biogas plants each with 998 kW of installed power



The ecosystem "Fattoria della Piana"

While biogas represents an ascertained useful source of renewable energy, the digestate ever-increasing production induces problems related to its sustainable discharge.

Consequently, the production of biogas has to be associated to a sustainable disposal of digestate for being economically and environmentally competitive with the fossil fuels.

The two biogas plants were differently supplied:

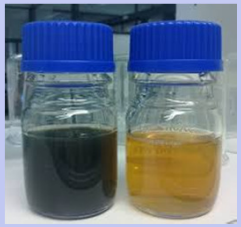
the first one named Fattoria (F) was powered with animal manures (poultry, cow and sheep), milk serum, maize silage and in minor amount with olive waste and citrus pulp.

The second one named Uliva (U) was mainly powered with olive waste and citrus pulp and in minor amount with animal manure and maize silage.

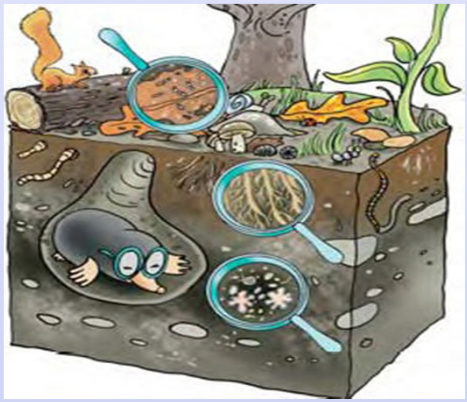
The objectives were :

1) **to evaluate if recalcitrant agriculture wastes (olive wastes and citrus pulps), mixed in different proportions with livestock manures, whey and maize silage produce biogas different in composition**

2) **to characterize the obtained digestates, each separated in liquid and solid fractions**



3) to verify the impact of the amendment with liquid (L) and solid fractions (S) of the two digestates on soil fertility



4) To check *cucumis sativus* growth and productivity in field amended with liquid (L) and solid fractions (S) of the two digestates

Cucumber *(Cucumis sativus* L.) is an important vegetable, and one of the most popular members of the Cucurbitaceae family. It is one of the oldest vegetables cultivated by man with historical records dating back 5,000 years.

Fertile soils are used for the cultivation of cucumber; infertile soils result in bitter and misshapen fruits which are often rejected by consumers.

Parameters	Units	Liquid fraction	Solid fraction
Total solids	%	$7^{b} \pm 3$	$25^{a} \pm 4$
Volatile organic compounds	Vol%	$63^{b} \pm 3$	$79^{a} \pm 5$
Moisture	%	$93^{a} \pm 5$	$75^{b} \pm 6$
COD	mg/L	$50{,}000 \pm 121$	–
BOD	mg/L	8500 ± 12	–
Total phenols	mg/L	$395^{a} \pm 12$	$325^{b} \pm 9$
Total oil	mg/L	200 ± 6	–
Fat (saponifiable)	mg/L	180 ± 6	–
Total hydrocarbons	mg/L	33 ± 1	–
pH		$8.3^{a} \pm 0.6$	$8.4^{a} \pm 0.5$
Fluorescein diacetate hydrolysis	µg fluorescein g^{-1} dm	$1.68^{b} \pm 0.5$	$2.45^{a} \pm 0.4$
Bacteria	CFU	$110 \times 10^{3b} \pm 5$	$140 \times 10^{3\ a} \pm 7$
Conductibility	µS/cm	$1879^{ab} \pm 10$	$1707^{a} \pm 11$
Total carbon	% dm	$39.5^{a} \pm 4$	$43^{a} \pm 5$
Organic matter	% dm	$69^{a} \pm 2$	$74^{a} \pm 5$
Total nitrogen	% dm	$4.9^{a} \pm 2$	$5.3^{a} \pm 3$
C/N		$8.1^{a} \pm 3$	$8.1^{a} \pm 2$
K^{+}	mg/L	$480^{b} \pm 9$	$960^{a} \pm 8$
K_2O	mg/L	$576^{b} \pm 11$	$1152^{a} \pm 7$
P	mg/L	$290^{b} \pm 9$	$560^{a} \pm 12$
P_2O_5	mg/L	$664^{b} \pm 16$	$1282^{a} \pm 11$
NO_3^{-}	mg/L	$140^{b} \pm 11$	$1500^{a} \pm 17$
NH_4^{+}	mg/L	$340^{a} \pm 12$	$30^{b} \pm 6$
Ca^{++}	mg/L	$600^{b} \pm 11$	$900^{a} \pm 15$
Mg^{++}	mg/L	$9^{b} \pm 2$	$100^{a} \pm 13$

Values are mean ± SE (n = 4). Different letters in the same row indicate significant differences $p \leq 0.05$

FATTORIA

Waste Biomass Valor 2016, 267-280.

Parameters	Units	Liquid fraction	Solid fraction
Total solid	%	$8^{b} \pm 3$	$40^{a} \pm 6$
Volatile substances	%	$73^{b} \pm 5$	$85^{a} \pm 4$
Moisture	%	$92^{a} \pm 8$	$60^{b} \pm 6$
COD	mg/L	94,000 ± 16	–
BOD	mg/L	16,000 ± 16	–
Total phenols	mg/L	$940^{a} \pm 12$	502^{b}
Total oil	mg/L	230 ± 10	–
Fat (saponifiable)	mg/L	200 ± 13	–
Total hydrocarbons	mg/L	36 ± 6	–
pH		$8.3^{a} \pm 1$	$8.4^{a} \pm 1.5$
FFluorescein diacetate hydrolysis	µg fluorescein g^{-1} dm	$1.18^{a} \pm 0.5$	$2.15^{a} \pm 0.6$
Bacteria colonies	CFU	$30 \times 10^{3b} \pm 2$	$55 \times 10^{3a} \pm 3$
EC	µS/cm	$1438^{a} \pm 3$	$1298^{b} \pm 5$
Total carbon	% dm	$37.5^{b} \pm 2$	$42.9^{a} \pm 2.5$
Organic matter	% dm	$65^{b} \pm 4$	$74^{a} \pm 3$
Total nitrogen	% dm	$4.7^{a} \pm 0.5$	$5.5^{a} \pm 0.6$
C/N		$7.97^{a} \pm 0.9$	$7.8^{a} \pm 0.8$
K^{+}	mg/L	$660^{a} \pm 15$	$300^{b} \pm 11$
K_2O	mg/L	$792^{a} \pm 8$	$360^{b} \pm 5$
P	mg/L	$250^{b} \pm 7$	$450^{a} \pm 5$
P_2O_5	mg/L	$573^{b} \pm 12$	$1030^{a} \pm 25$
NO_3^{-}	mg/L	$100^{b} \pm 5$	$400^{a} \pm 15$
NH_4^{+}	mg/L	$260^{a} \pm 15$	$40^{b} \pm 3$
Ca^{++}	mg/L	$700^{b} \pm 8$	$1400^{a} \pm 17$
Mg^{++}	mg/L	$150^{a} \pm 7$	$50^{b} \pm 5$

ULIVA

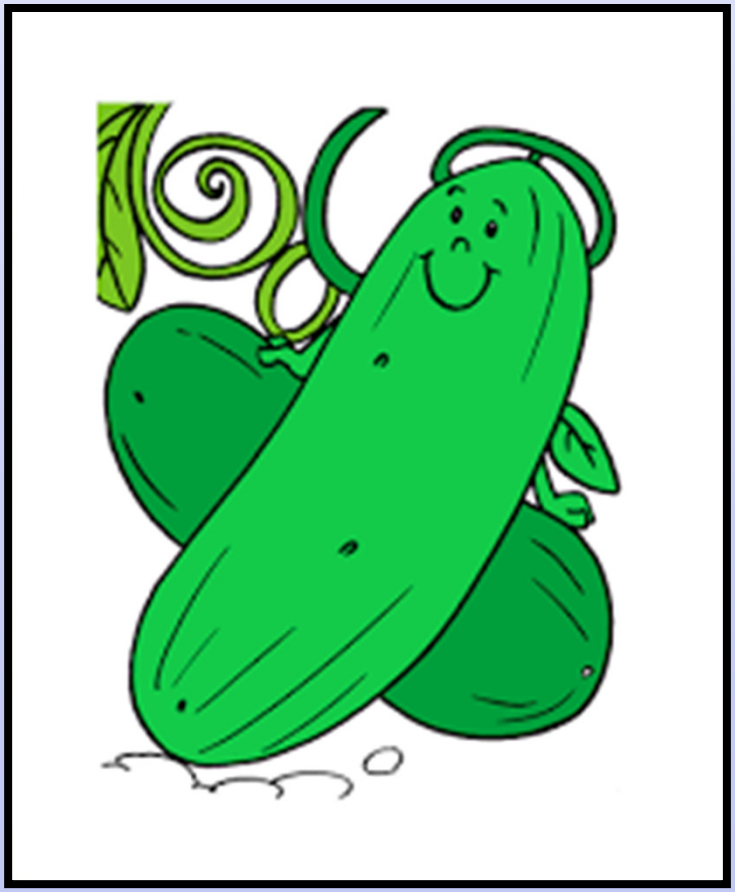
Values are mean ± SE (n = 4). Different letters in the same row indicate significant differences $p \leq 0.05$

SOIL QUALITY

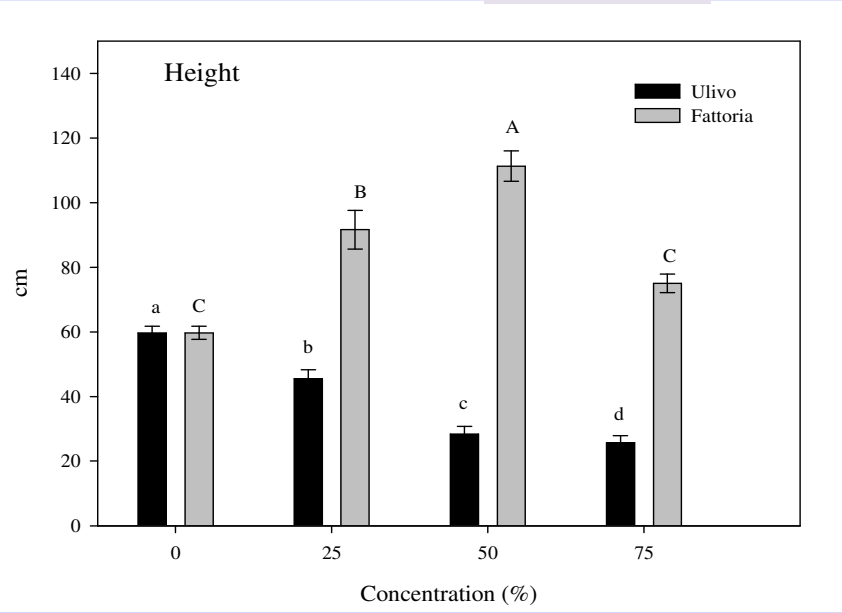
The observed changes in soil chemical characteristics depended on the source of digestate, the type of fraction, and the concentration used. The improvement of soil chemical and biological properties was greater with both fractions of the digestate Fattoria.

			FATTORIA			
		OM	WSP	FDA.	MBC	CAT
SOLID						
	F-ratio	32.598	191.81	128.99	1062.31	118.88
	p value	0.000	0.000	0.000	0.000	0.000
	R^2	0.924	0.986	0.980	0.997	0.978
LIQUID						
	F-ratio	0.067	40.43	270.77	518.56	336.70
	p value	0.024	0.000	0.000	0.000	0.000
	R^2	0.976	0.969	0.990	0.995	0.992
			ULIVA			
		OM	WSP	FDA	MBC	CAT
SOLID						
	F-ratio	12.72	1104.33	1.33	98.97	18.42
	p value	0.002	0.000	ns	0.000	0.001
	R^2	0.827	0.998	0.34	0.974	0.874
LIQUID						
	F-ratio	0.067	247.79	0.82	3.13	28.73
	p value	0.024	0.000	ns	ns	0.000
	R^2	0.976	0.989	0.52	0.540	0.915

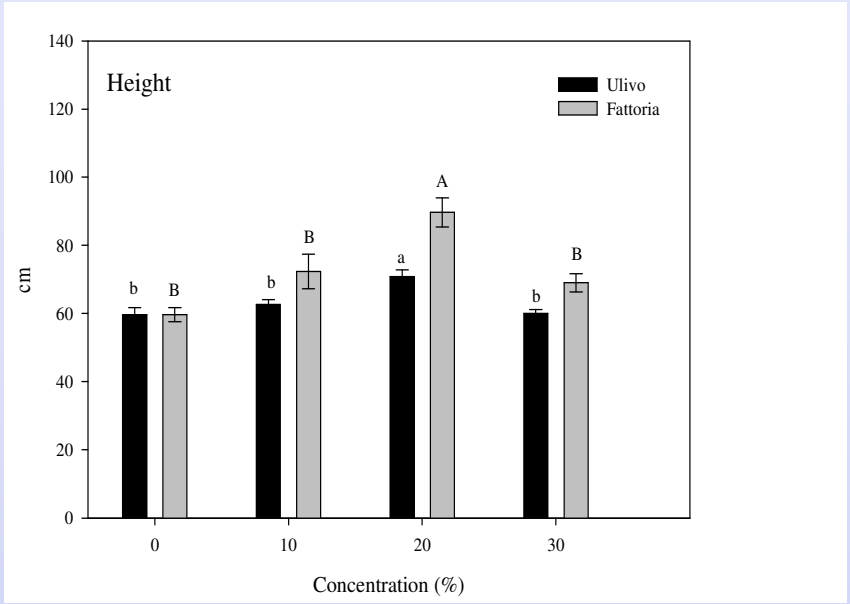
CUCUMBER GROWTH

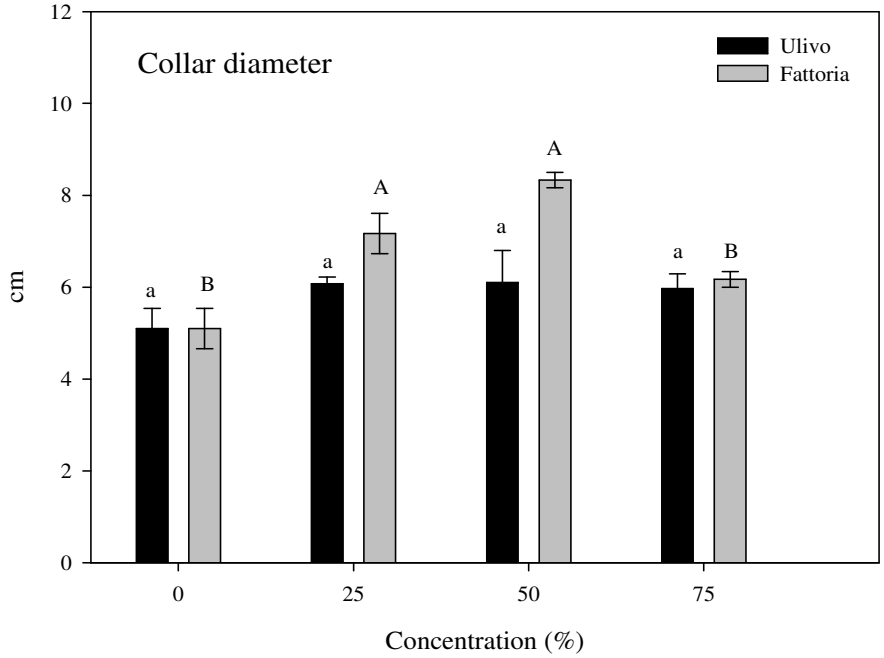


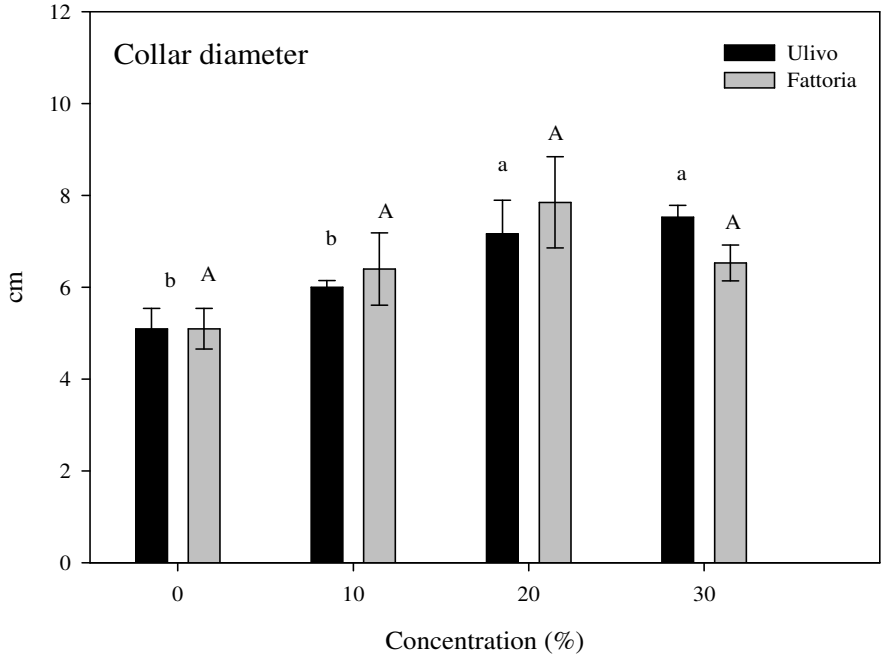
Solid



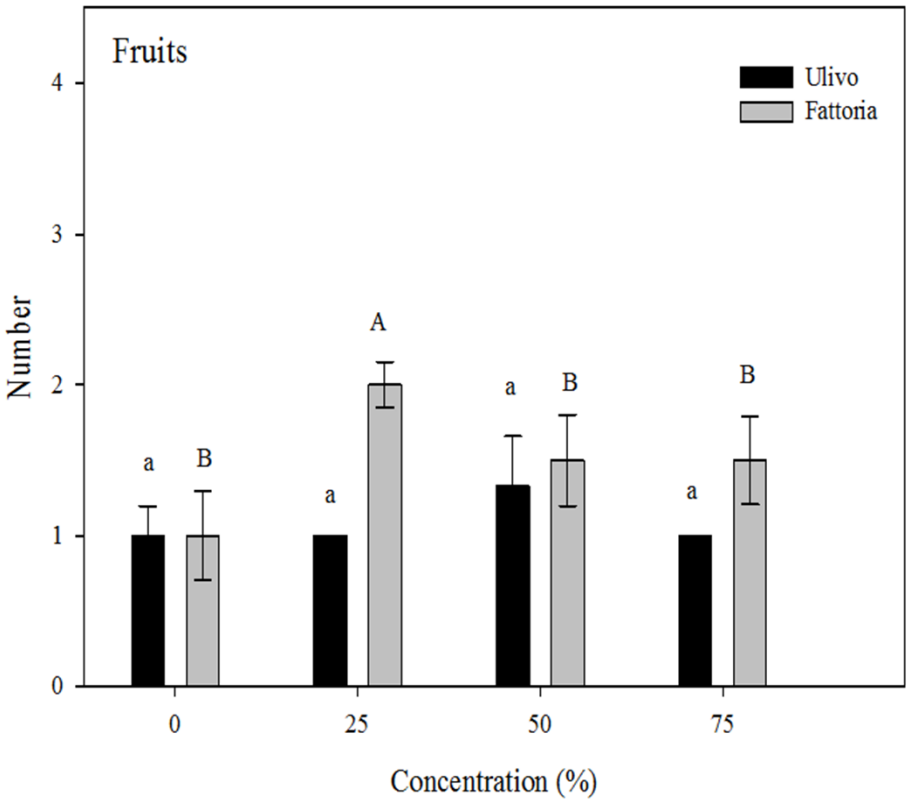
Liquid



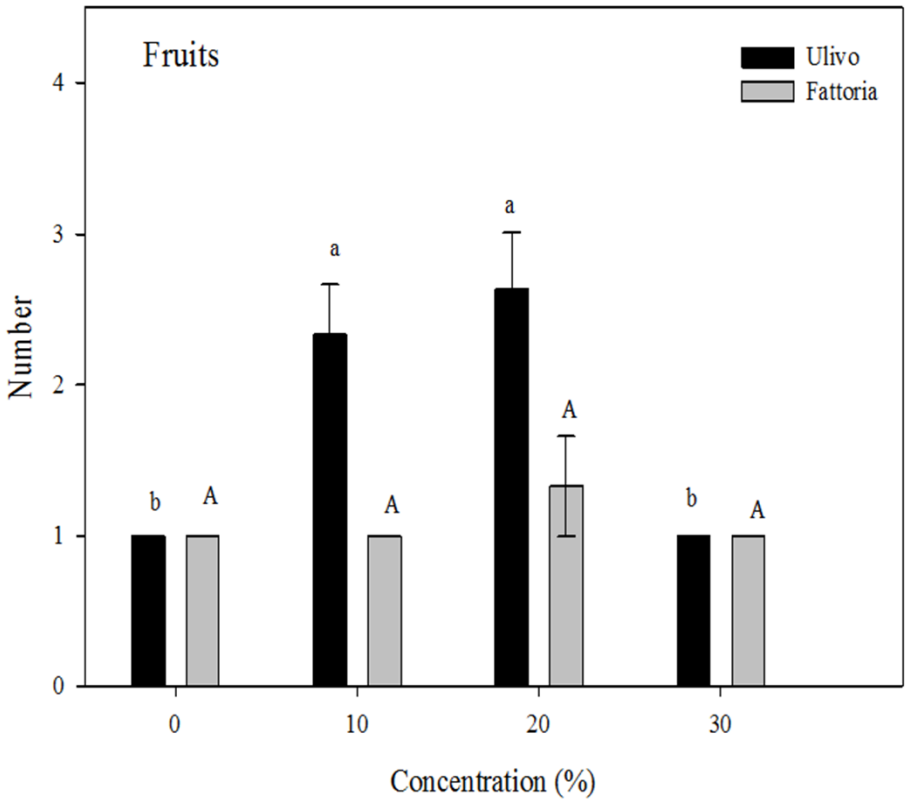




SOLID

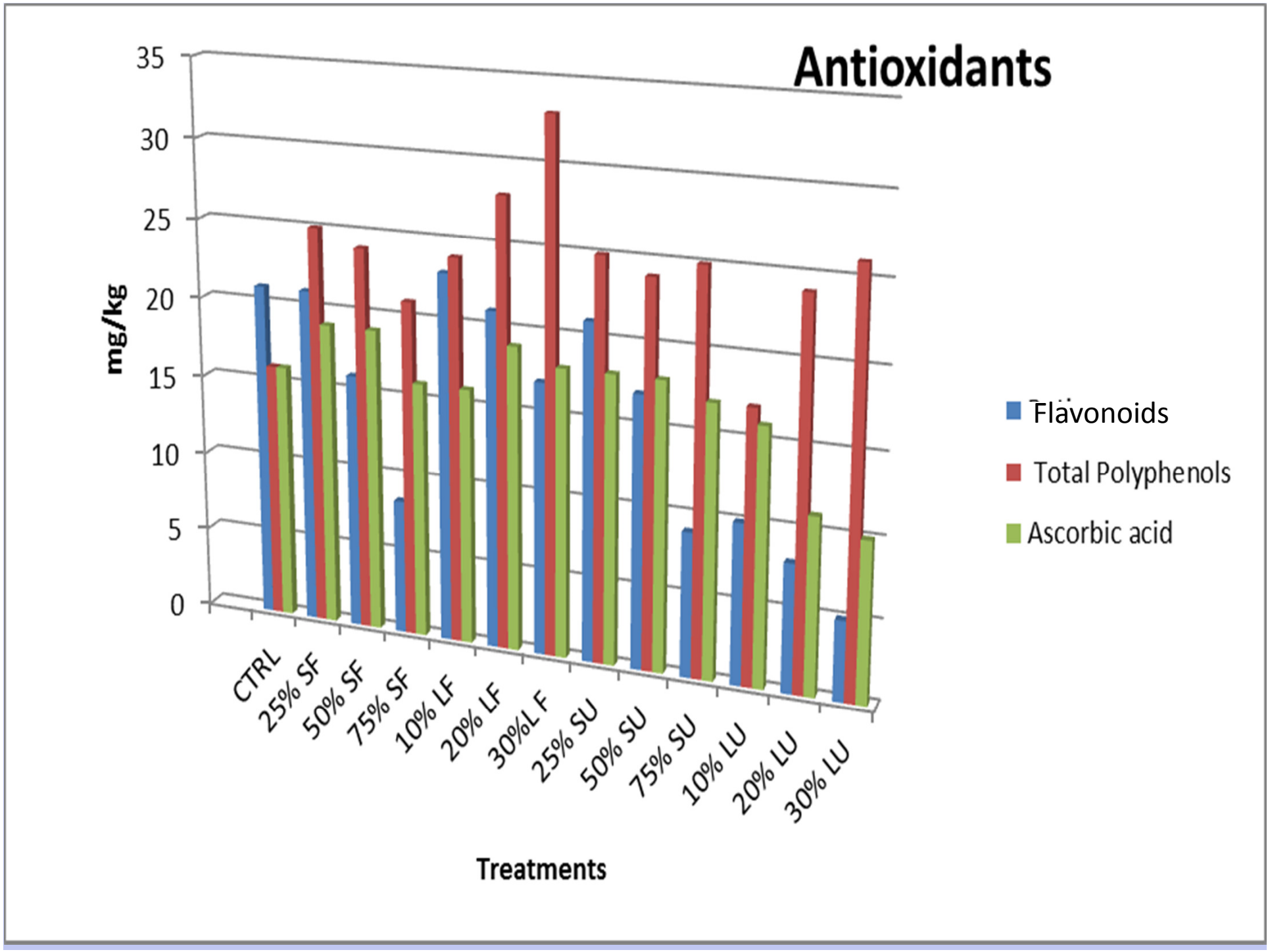


LIQUID



Cucumber Nutraceutical Properties

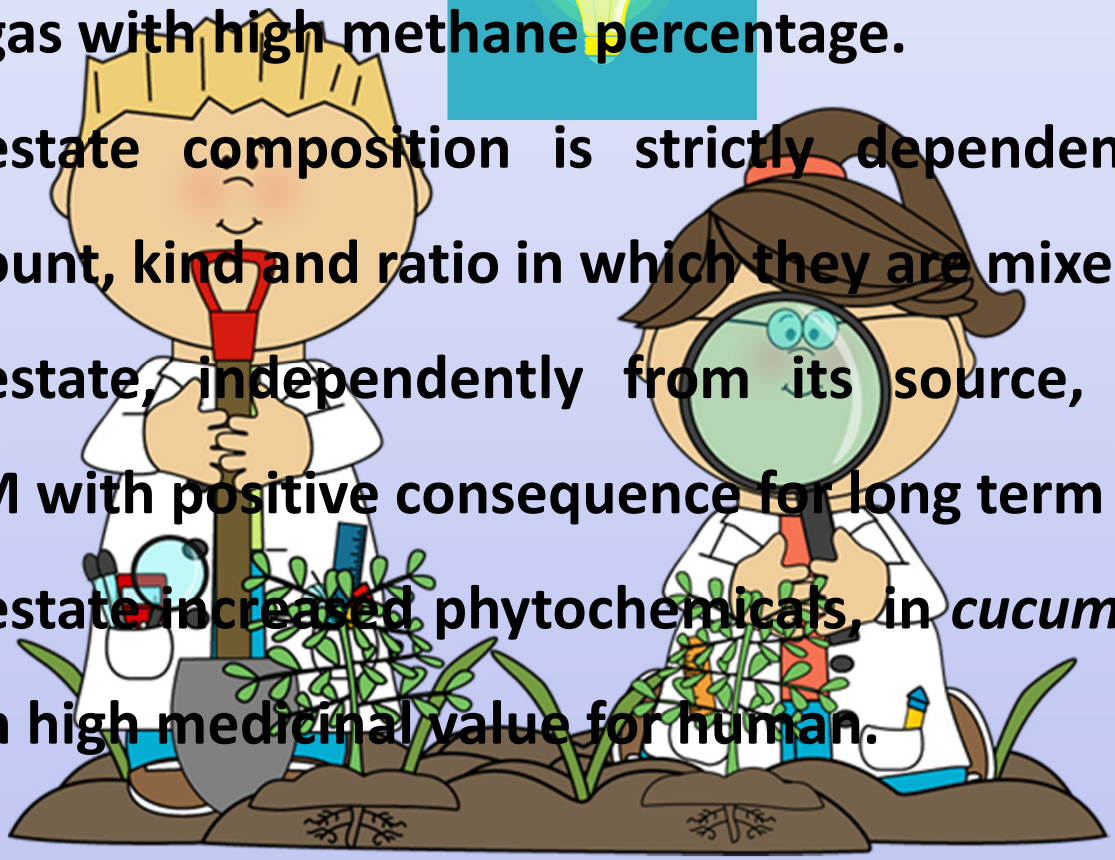
	Chroma Peel	Chroma Pulp	BRIX	pH	Tritabile acidity	Dry matter	DPPH %
Control	22 ^{c}	97 ^{a}	4.05 ^{a}	6.7^{b}	0.70^{b}	3.7^{b}	13.2^{e}
Solid Fattoria							
25%	25^{b}	99^{a}	3.25^{b}	6.78^{ab}	0.72^{b}	3.3 ^{b}	22.5^{c}
50%	29^{a}	101^{a}	3.80 ^{a}	6.70^{b}	0.70^{b}	3.3 ^{b}	21.2^{c}
75%	21^{c}	99^{a}	3.85 ^{a}	6.81^{a}	0.50^{c}	3.4 ^{b}	13.5^{e}
Liquid Fattoria							
10%	13^{e}	98^{a}	3.70^{ab}	6.80^{a}	0.55^{c}	3.6 ^{b}	13.1
20%	16^{d}	86^{b}	3.73^{ab}	6.75^{ab}	0.76^{b}	3.9 ^{b}	17.8^{e}
30%	17^{d}	85^{b}	3.81^{a}	6.90^{a}	0.78^{b}	4.8 ^{a}	31.2^{a}
Solid Ulivo							
25%	23^{c}	97 ^{a}	3.35^{c}	6.70^{b}	0.84^{ab}	3.5 ^{b}	19.1^{d}
50%	22^{c}	96 ^{a}	3.21^{b}	6.71^{b}	0.80^{b}	3.7 ^{b}	20.3^{d}
75%	23^{c}	96 ^{a}	3.30^{bc}	6.80^{a}	0.89^{a}	3.8 ^{b}	13.9^{e}
Liquid Ulivo							
10%	21^{c}	98 ^{a}	3.41^{bc}	6.14^{e}	0.73^{b}	4.7 ^{a}	24.5^{b}
20%	22^{c}	95 ^{a}	3.44 ^{bc}	6.32^{d}	0.76^{b}	4.9 ^{a}	14.2^{e}
30%	23^{c}	96 ^{a}	3.55 ^{b}	6.46^{c}	0.78^{b}	4.8 ^{a}	13.8^{e}


Antioxidants
35
30
25
20
15
10
5
0
mg/kg
CTRL
25% SF
50% SF
75% SF
10% LF
20% LF
30%L F
25% SU
50% SU
75% SU
10% LU
20% LU
30% LU
Treatments
Flavonoids
Total Polyphenols
Ascorbic acid

	Vanillic acid mg/l	Syringic acid mg/l	Ferulic acid mg/l	p-cumaric acid mg/l	quercetin mg/l	Chlorogenic acid mg/l	narirutin mg/l	naringina mg/l	esperidin mg/l	neohesperidi no mg/l	esperetina mg/l	didimina mg/l	ramnetina mg/l	TOTAL mg/kg
	PHENOLS							FLAVONOIDS						
CTRL	LOQ	0.096	0.009	LOQ	0.221	2.042	0.203	0.203	0.435	LOQ	LOQ	LOQ	0.543	26.01
SF 25%	0.129	0.032	0.036	LOQ	0.218	2.033	0.173	0.289	0.070	0.071	0.367	0.011	0.287	27.04
SF 50%	0.074	LOQ	LOQ	LOQ	0.220	1.994	0.149	0.241	LOQ	0.045	0.373	LOQ	0.334	26.49
SF 75%	0.019	0.025	LOQ	LOQ	0.218	LOQ	LOQ	0.214	0.031	LOQ	0.364	LOQ	0.445	10.49
LF 10%	0.456	LOQ	0.020	LOQ	0.220	2.052	LOQ	0.388	LOQ	0.1480	0.367	LOQ	0.264	31.26
LF 20%	0.109	LOQ	0.069	LOQ	0.222	LOQ	0.142	0.393	0.062	0.065	0.370	LOQ	0.323	12.83
LF 30%	0,027	0.028	LOQ	LOQ	0.221	LOQ	LOQ	0.394	0.087	LOQ	0.365	LOQ	0.365	11.54
SU 25%	0.118	0.029	0.034	LOQ	0.213	2.030	0.168	0.274	0.078	0.068	0.359	0.015	0.281	26.65
SU 50%	0.067	LOQ	LOQ	LOQ	0.210	1.987	0.169	0.239	LOQ	0.041	0.365	LOQ	0.345	26.41
SU75%	0.016	0.026	LOQ	LOQ	0.207	LOQ	LOQ	0.210	0.047	LOQ	0.361	LOQ	0.461	10.49
LU 10%	0.370	LOQ	LOQ	LOQ	0.223	2.064	0.324	0.302	LOQ	0.134	0.365	0.045	0.301	31.76
LU 20%	0.118	LOQ	LOQ	LOQ	0.218	LOQ	0.182	0.239	LOQ	0.053	0.368	LOQ	0.327	11,92
LU 30%	0.027	0.028	LOQ	LOQ	0.221	LOQ	LOQ	0.394	0.087	LOQ	0.365	LOQ	0.365	11.54

CONCLUSIONS

1. **Animal and recalcitrant agriculture wastes produce biogas with high methane percentage.**
2. **Digestate composition is strictly dependent on the amount, kind and ratio in which they are mixed.**
3. **Digestate, independently from its source, enhanced SOM with positive consequence for long term fertility**
4. **Digestate increased phytochemicals, in *cucumis sativus*, with high medicinal value for human.**



Other possible use of solid digestate

- The
- r ash
- as a
- oard
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- nimal

feeding

Thanks