# NEW STUDIES ON SERICULTURE IN POLAND

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# SILKWORM WASTE MANAGEMENT IN BIOGAS PRODUCTION

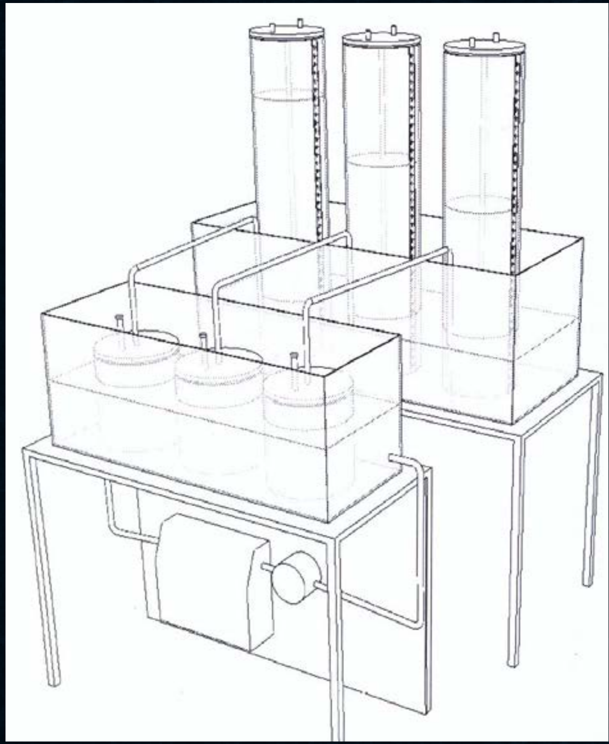
# A FEW WORDS ABOUT...

1. Increasing demand of organic agriculture, waste utilization and environmental protection.
2. Sericulture focuses not only on the cocoon production.
3. New ways that can benefit the farm's economy.
4. New sources of income for small-scale farmers not only through cocoon selling, but also by the multiple uses of by-products.
5. Insect farming technology provides a cheap source of biomass.
6. Small-scale farmers may produce 250-300 kg of silkworm waste - equivalent to 2 500 kg farm manure.

# MATERIAL AND METHODS

1. Two substrates collected: the breeding waste and the larvae excrement.
2. Chemical composition analysis according to PN-92/P-50092 standard.

3. Analyses of biogas and methane efficiency under mesophilic conditions in the Laboratory of Ecotechnologies, the Institute of Biosystems Engineering, the Poznan University of Life Sciences, Poland in 3 replications, according to the Polish standard:
   - total solids (TS, dried mass) PN-75C-04616/01 - drying samples for 24 h at 105˚C,
   - volatile total solids (VTS, organic dried mass) PN-Z-15011-3 - combustion of samples at 550˚C for 3 hours.
4. The Hydraulic Retention Time (HRT) tested based on the modified German standard DIN 38414/S8.
5. The experimental biogas production through anaerobic digestion was run in a multichamber biofermenter set.
6. The daily biogas production recorded every day accurate to 0.01 $dm^3$.




Multichamber biofermenter

# RESULTS

breeding waste pH: 6.49-7.25
excreta pH: 7.43-8.17

1. Minerals content higher in the mulberry material.
2. Celullose and lignin content higher in excrement.
3. The percentage of total solids in the inoculum was much lower.
4. Level of volatile total solids was similar.

| Substrate | Inoculum | Silkworm excrement | Breeding waste |
|---|---|---|---|
| Total solids (% TS) | 2.80 | 31.87 | 25.67 |
| Volatile total solids (% VTS) | 71.02 | 79.07 | 82.81 |

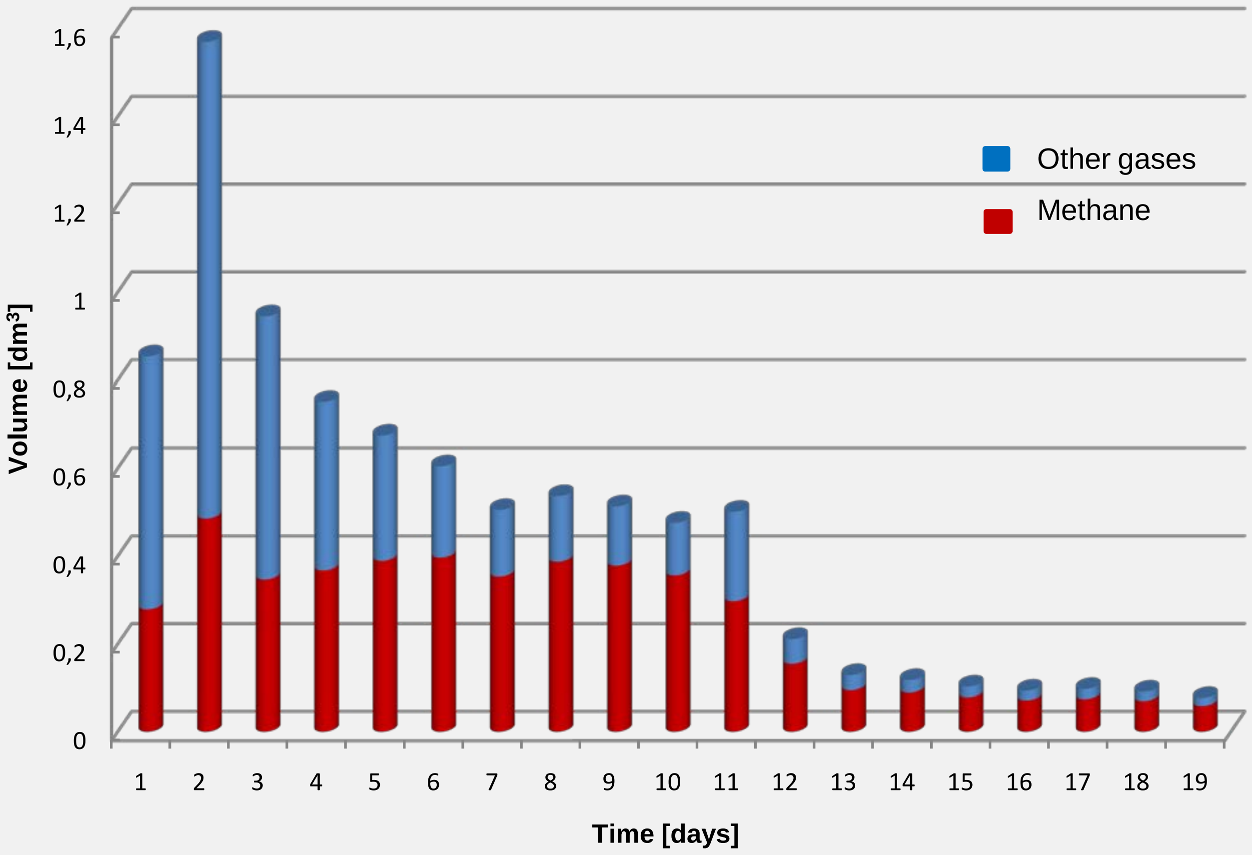
Results of physicochemical properties of substrates.

| Component | Mulberry leaves [%] | Silkworm excrement [%] |
|---|---|---|
| **Total minerals** (ash) | 16.62 | 13.00 |
| **Nitrogen** | 2.80 | 3.75 |
| **Carbon** | 41.59 | 42.31 |
| **C/N ratio** | 14.85 | 11.28 |
| **Cellulose** | 18.69 | 20.24 |
| **Holocellulose** | 55.97 | 54.82 |
| **Lignin** | 10.07 | 14.76 |
| **Moisture content** | 7.60 | 8.70 |

Results of chemical composition analyses of materials.

# RESULTS

One distinct pick - simple organic compounds rapidly degradated by the hydrolytic bacteria.
Biogas and methane production was at a relatively high level until 11th day.

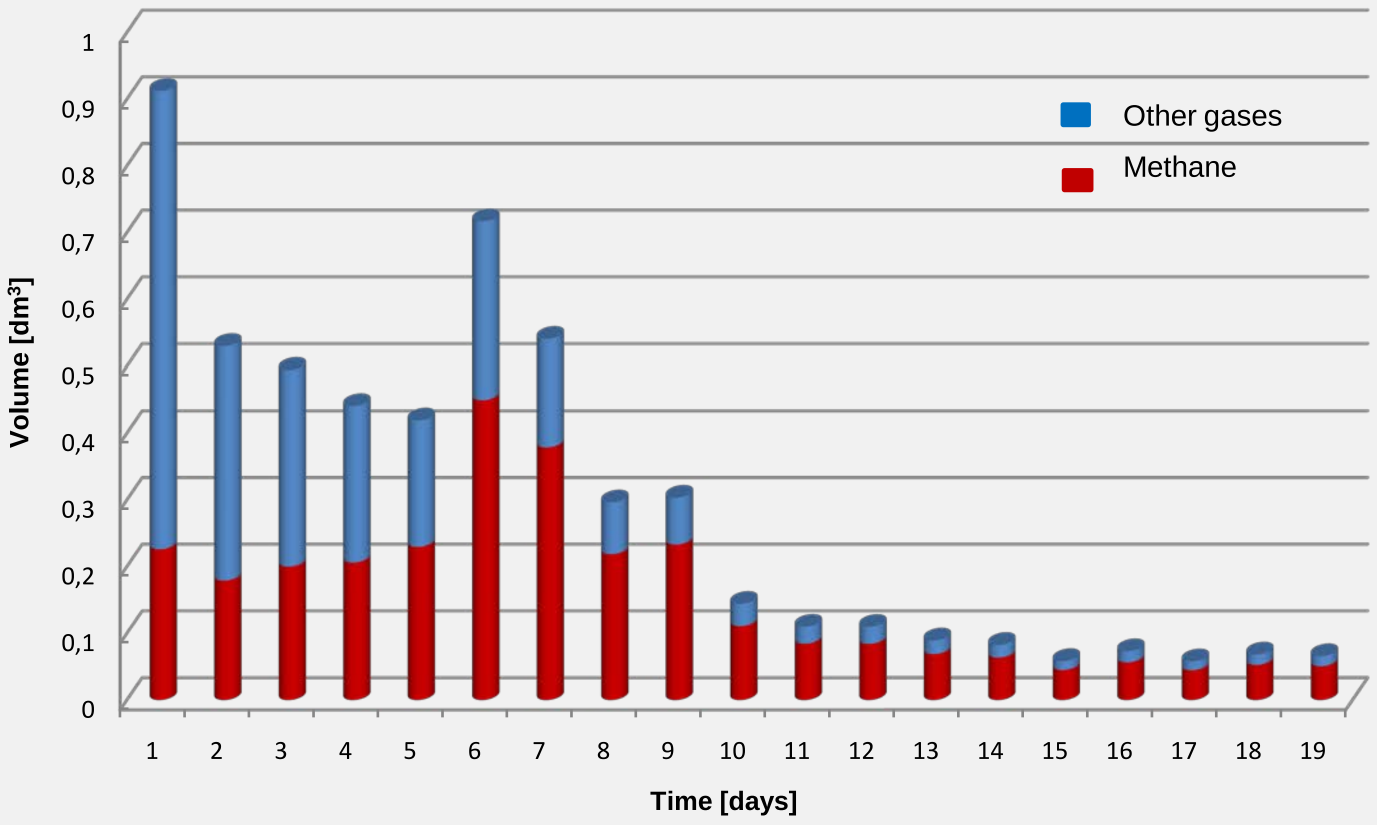



Daily biogas production during methane fermentation of breeding waste.

| Day of fermentation | Biogas production [%] | Cumulative $CH_4$ production [%] |
|---|---|---|
| 1 | 8,80 | 5,51 |
| 2 | 16,42 | 15,56 |
| 3 | 10,88 | 22,99 |
| 4 | 8,80 | 30,68 |
| 5 | 7,62 | 38,59 |
| 6 | 6,78 | 46,55 |
| 7 | 6,00 | 54,06 |
| 8 | 6,19 | 62,10 |
| 9 | 5,52 | 69,44 |
| 10 | 5,07 | 76,28 |
| 11 | 5,68 | 83,39 |
| 12 | 2,28 | 86,46 |
| 13 | 1,66 | 88,69 |
| 14 | 1,35 | 90,54 |
| 15 | 1,31 | 92,32 |
| 16 | 1,04 | 93,75 |
| 17 | 1,23 | 95,43 |
| 18 | 1,05 | 96,87 |

# RESULTS

Two distinct picks - simple organic compounds rapidly degradated by bacteria,
then complex compounds (lipids, fatty acids) and metabolic products of larvae.
Biogas and methane production was at a relatively high level until 9th day.




Daily biogas production during methane fermentation of silkworm excrement.

| Day of fermentation | Biogas production [%] | Cumulative $CH_4$ production [%] |
|---|---|---|
| 1 | 16.37 | 7.40 |
| 2 | 9.59 | 13.42 |
| 3 | 8.36 | 19.65 |
| 4 | 7.40 | 26.06 |
| 5 | 8.36 | 34.47 |
| 6 | 13.35 | 49.61 |
| 7 | 10.19 | 62.64 |
| 8 | 5.57 | 70.13 |
| 9 | 4.97 | 77.07 |
| 10 | 2.56 | 80.68 |
| 11 | 2.01 | 83.51 |
| 12 | 2.11 | 86.49 |
| 13 | 1.65 | 88.82 |
| 14 | 1.52 | 90.96 |
| 15 | 1.25 | 92.72 |
| 16 | 1.24 | 94.46 |
| 17 | 1.08 | 96.00 |
| 18 | 1.51 | 98.13 |

# RESULTS

1. Both of the substrates were decomposed in 19 days.
2. Approximately 80% of methane production was recorded in the first 10 days,
   - 17 days for maize straw silage (Cieślik et al. 2016),
   - 30 days for microalgal biomass (Kwietniewska and Tys 2014),
   - 30-35 days for chicken manure (Niu et al. 2014; Wang et al. 2014),
   - 24 days for pig slurry co-digested with olive pomace oil (Orive et al. 2016).
3. Methan content 50-52% of biogas,
   - 46-57% for chicken manure (Lewicki et al. 2016),
   - 52% for maize straw silage (Cieślik et al. 2016),
   - 53% for bread waste and 68-69% for fish wastes (Kafle et al. 2013),
   - 50-60% for cattle manure and 60% pig manure (Dobre et al. 2014).

Biogas and methane efficiencies of analyzed substrates

| **Sample** | **$CH_4$ content (%)** | **Fresh mass ($m^3$/Mg FM)** | | **Total solids ($m^3$/Mg TS)** | | **Volatile total solids ($m^3$/Mg VTS)** | |
|---|---|---|---|---|---|---|---|
| | | cumulated biogas | cumulated $CH_4$ | cumulated biogas | cumulated $CH_4$ | cumulated biogas | cumulated $CH_4$ |
| **excrement** | 50.4 | 105.81 | 53.33 | 331.97 | 167.31 | 419.82 | 211.59 |
| **breeding waste** | 52.4 | 125.59 | 65.81 | 489.24 | 256.36 | 590.77 | 309.56 |

# CONCLUSION

1. The process of fermentation ran smoothly, without inhibition or pH interference.
2. Breeding waste characterized by 2% higher methane content than excrement.
3. Biogas had a high methane content, which significantly increases the biogas calorific value.
4. The fermentation process was relatively short (19 days) – good material for cheap and fast energy.
5. Thanks to the relatively short time of methane production (HRT) and high content of dry matter, biogas production is more efficient in comparison to common used agricultural manures.
6. Producing biogas from silkworm waste may be a good source of additional income for small-scale farmers.
7. Excreta and breeding waste turned out to be a very good feedstock for biogas production.

More information and details of research

Łochyńska M., Frankowski J. 2018.
„The biogas production potential from silkworm waste”. Waste Management 79: 564–570.

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# The biogas production potential from silkworm waste

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# THE EFFECTS OF SILKWORM EXCREMENT ORGANIC FERTILIZER ON HEMP YIELD

# Breeding waste in crops fertilization

- organic fertilizers and organic farming are very popular and required,
- organic fertilizer – silkworm breeding waste,
- cheap source of waste,
- Lack of chemicals, detergents, antibiotics etc.,
- 250-300 kg – waste management,
- very impressive results of crops yield fertilization - China:
    - cucumber,
    - maize,
    - broccoli,
    - peanuts,
    - rise,
    - tomatoe,
    - lettuce,
    - cabagge,
    - melon,
    - pepper,
    - flowers.


Excreta of larvae I and V instar

Breeding waste

# Model plant – hemp *Cannabis sativa* L.

- organic hemp fertilization hardly known,
- a new Henola cultivar registered in 2018,
- relatively short wegetation period,
- relatively low plants,
- direction of use – seed production,
- result of fertilization visible in seed yield.

# Materials and methods

- breeding waste from 2015 and 2016,
- experiment in pots – 2016 (R1), 2017 (R2), 2018 (R3),
- Dose of fertilization – 15 t/ha, 30 t/ha, control,
- 3 repetitions of each combination,
- 8 plants/pot,
- pot – 16 l of soil.




# Materials and methods

- Chemical composition of soil before and after fertilization,
- Mineral composition of breeding waste,
- Chemical composition of hemp,
- Total length, technical lenght, lenght of hemp panicles,
- Analysis of hemp yield: total yield, straw and seed yield,
- Statistic analysis ANOVA.

Panicles of hemp

# Results

| Dose | | pH | $P_2O_5$ | $K_2O$ | Mg | Mn | Cu | Zn | Fe | S | B |
|---|---|---|---|---|---|---|---|---|---|---|---|
| R1 | control | 7.5 | 43.0 | 12.1 | 12.3 | 90.0 | 3.2 | 16.2 | 320 | 24.9 | 2.3 |
| | 15 t/ha | 7.7 | 42.5 | 13.5 | 10.1 | 94.0 | 3.3 | 14.8 | 343 | 25.0 | 2.3 |
| | 30 t/ha | 7.8 | 45.5 | 15.5 | 10.7 | 94.0 | 2.8 | 16.2 | 329 | 25.7 | 2.3 |
| R2 | control | 6.7 | 39.0 | 22.1 | 10.9 | 79.6 | 3.1 | 7.8 | 419 | 25.3 | 2.4 |
| | 15 t/ha | 6.9 | 40.5 | 27.7 | 10.8 | 87.0 | 3.0 | 7.0 | 350 | 25.4 | 2.4 |
| | 30 t/ha | 7.0 | 41.0 | 31.0 | 10.4 | 87.3 | 3.1 | 6.8 | 372 | 25.6 | 2.4 |
| R3 | control | 7.0 | 48.0 | 15.2 | 5.9 | 89.5 | 2.9 | 7.5 | 419 | 25.0 | 2.4 |
| | 15 t/ha | 7.2 | 49.0 | 20.5 | 6.0 | 84.7 | 3.3 | 7.9 | 442 | 25.6 | 2.4 |
| | 30 t/ha | 7.2 | 52.0 | 24.5 | 6.1 | 79.5 | 3.1 | 7.7 | 434 | 25.7 | 2.4 |

Results of chemical composition analysis of soil in 3 years of studies (in mg/kg).

# Results

| Year | | | % FM | | | | | mg/kg DM | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | pH | DM% | N | $P_2O_5$ | $K_2O$ | CaO | MgO | Cu | Mn | Zn | Cd | Pb |
| **2015** | 7.43 | 82.74 | 2.53 | 0.95 | 2.55 | 3.10 | 0.58 | 10.9 | 71.9 | 18.1 | <0.111 | <2.07 |
| **2016** | 7.25 | 86.82 | 2.56 | 1.0 | 2.7 | 3.24 | 0.56 | 8.64 | 67.4 | 15.6 | <0.138 | <1.20 |

Results of chemical composition analysis of breeding waste.

# Results

| Dose | | Cellulose | Lignins | Pentozans | Holocellulose | Minerals |
|---|---|---|---|---|---|---|
| **R1** | control | 47.68 | 14.58 | 17.47 | 79.22 | 5.02 |
| | 15 t/ha | 47.64 | 14.18 | 19.78 | 79.54 | 5.01 |
| | 30 t/ha | 46.43 | 14.79 | 19.31 | 79.04 | 4.38 |
| **R2** | control | 48.48 | 14.5 | 19.22 | 77.78 | 4.68 |
| | 15 t/ha | 50.72 | 15.43 | 16.54 | 76.31 | 4.01 |
| | 30 t/ha | 49.1 | 15.4 | 17.11 | 77.41 | 3.96 |
| **R3** | control | 47.42 | 13.85 | 18.5 | 76.44 | 5.17 |
| | 15 t/ha | 46.38 | 14.92 | 18.74 | 76.83 | 5.64 |
| | 30 t/ha | 46.37 | 15.34 | 18.17 | 76.24 | 5.23 |

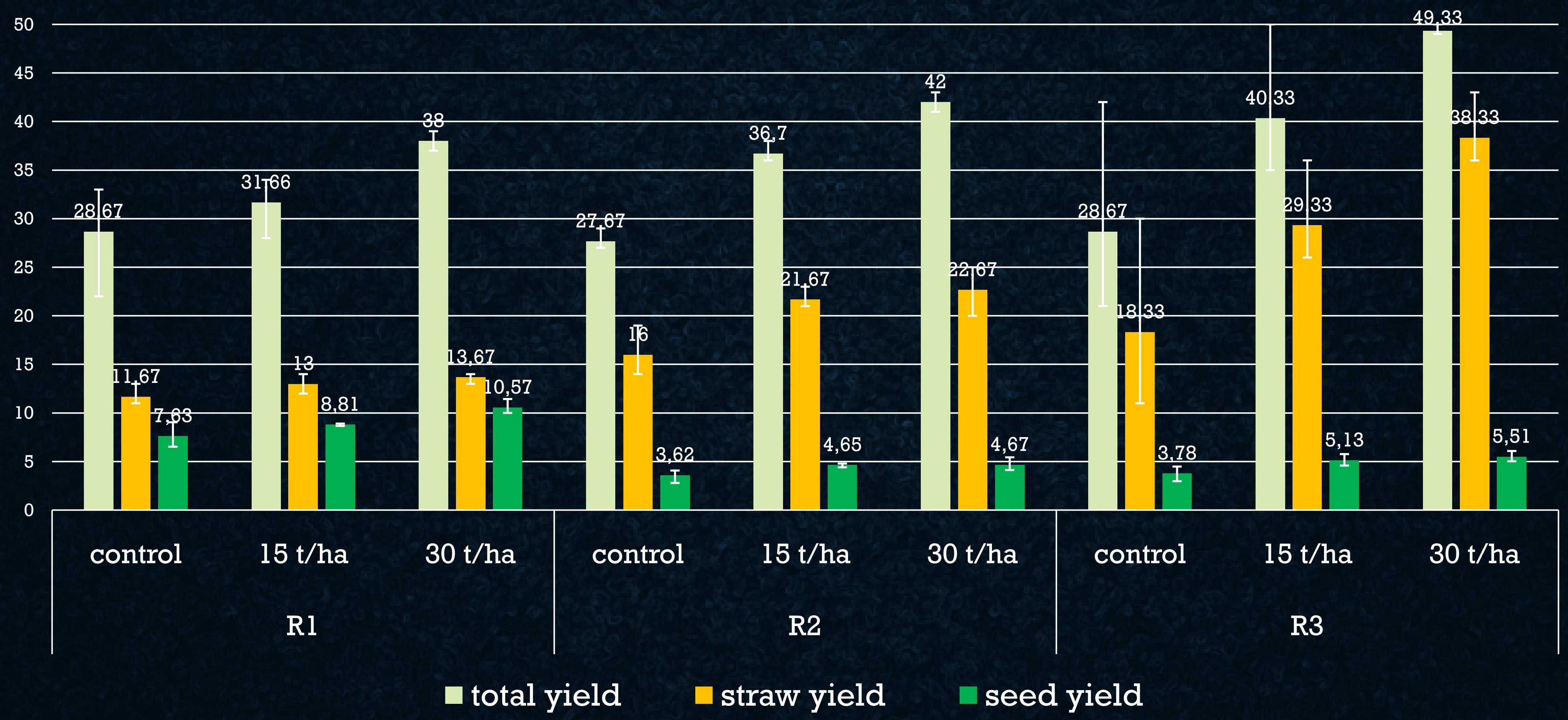
Results of chemical composition analysis of hemp biomass (in %).

# Results

| | R1 | | | R2 | | | R3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | control | 15 t/ha | 30 t/ha | control | 15 t/ha | 30 t/ha | control | 15 t/ha | 30 t/ha |
| **Total yield** | 28.67 | 31.66 | 38.0 | 27.67 | 36.7 | 42.0 | 28.67 | 40.33 | 49.33 |
| **Straw yield** | 11.67 | 13.0 | 13.67 | 16.0 | 22.67 | 34.0 | 18.33 | 29.33 | 38.33 |
| **Seed yield** | 7.63 | 8.81 | 10.57 | 3.62 | 4.65 | 4.77 | 3.78 | 5.13 | 5.51 |

Medium values of total yield, straw and seed yields in 3 years of stuides (in g).

# Results



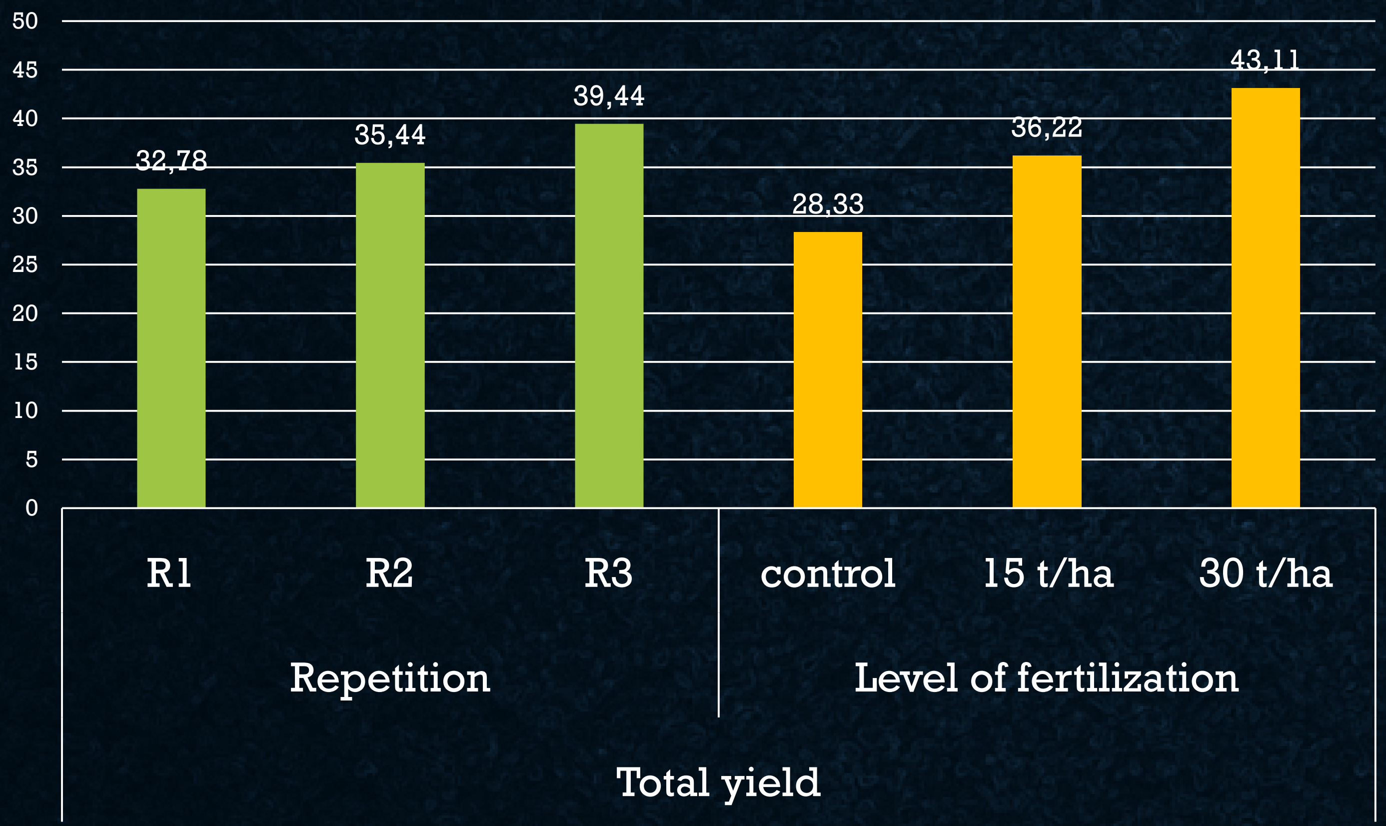

Medium values of total yield, straw and seed yields in 3 years of stuides (in g).

# Results

Statistical analysis:

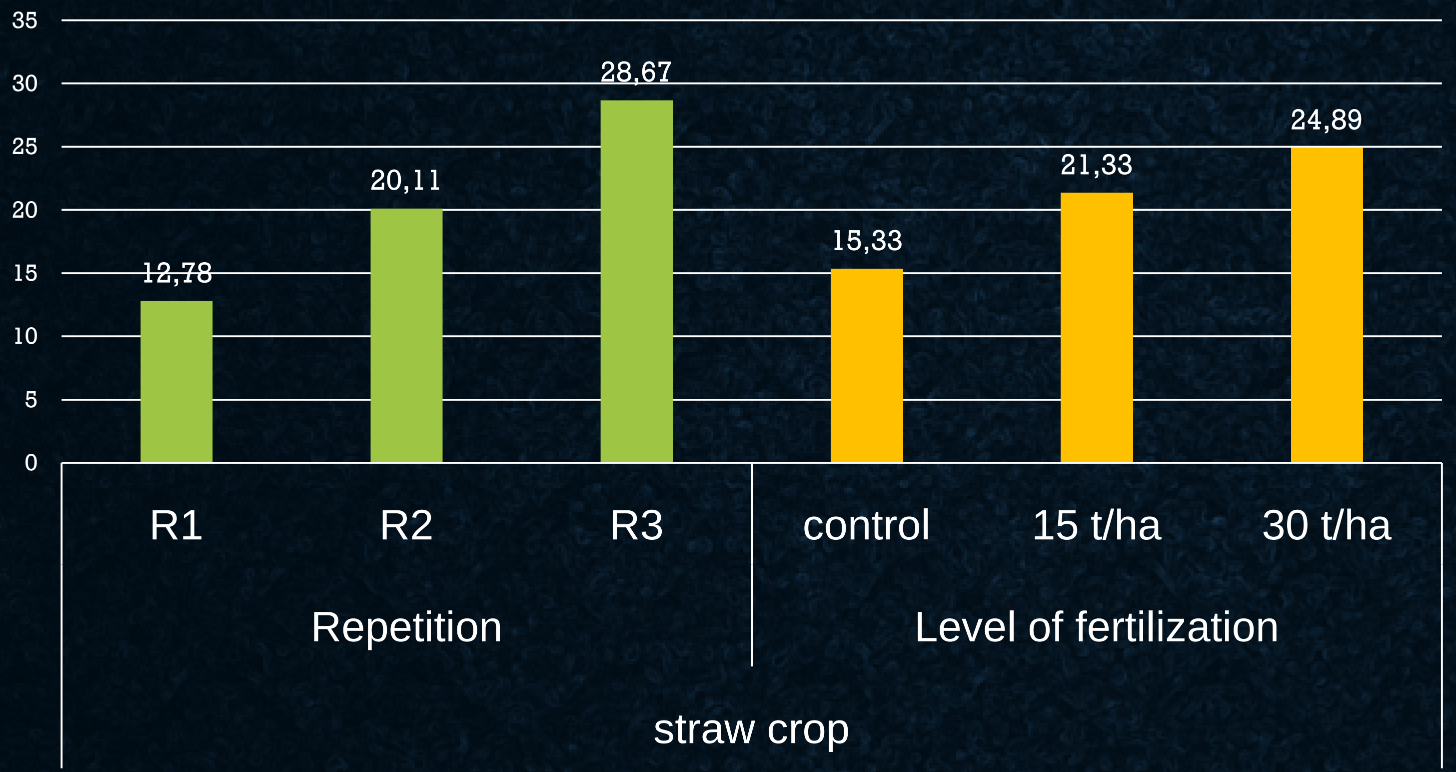
- Strong corelation between pH of soil and seed yield (r = 0,96, p < 0.01), between straw yield and cellulose content (r = 0.81, p < 0.01) and between hemp yield and dose of fertilization (r = 0,90, p < 0.01).
- ANOVA test – significant differences between fertilisation dose and total yield ($F = 17.59$, $p < 0.001$, $\Delta\eta^2 = 0.66$), straw yield ($F = 11.03$, $p < 0.001$, $\Delta\eta^2 = 0.55$) and seed yield ($F = 16.68$, $p < 0.001$, $\Delta\eta^2 = 0.65$).

# Results



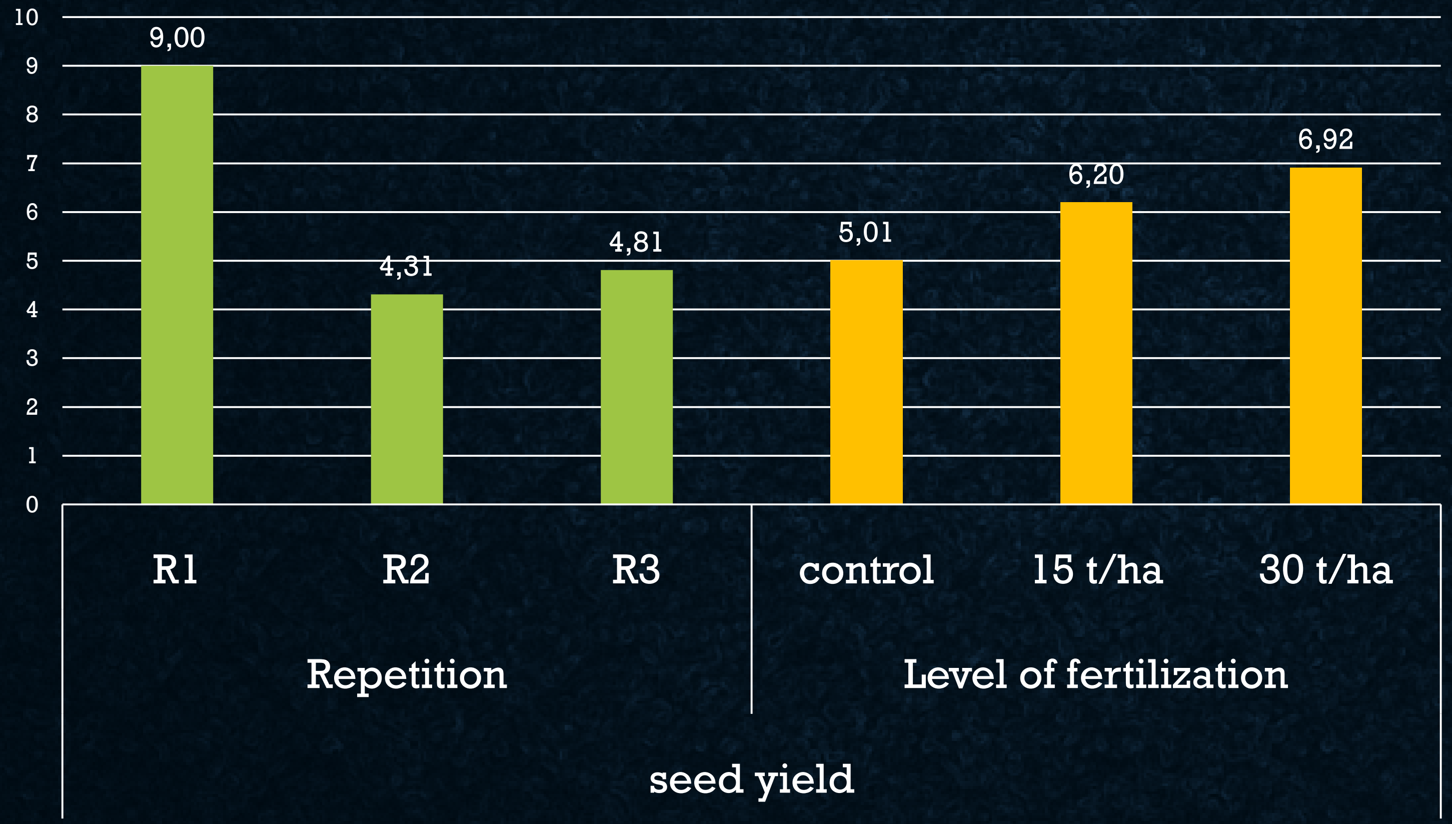

Results of post hoc test for impact of repetition and fertilisation dose on total yield.

# Results




Results of post hoc test for impact of repetition and fertilisation dose on straw yield.

# Results




Results of post hoc test for impact of repetition and fertilisation dose on seed yield.

# Results

1. Organic fertilisation significantly affects the hemp yield.
2. Breeding waste improves pH of soil, organic material and minerals content in soil.
3. Fertilisation of Henola cultivar do not affect the cellulose content.
4. Total yield higher than control: R1 – 32,5%, R2 – 51,8%, R3 – 22,3%.
5. Straw yield higher than control: R1 – 17,1%, R2 – 115%, R3 – 109%.
6. Seed yield higher than control: R1 – 38,5%, R2 – 31,7%, R3 – 45,7%.

Results in review:

Łochyńska M., Frankowski J. The effects of silkworm excrement organic fertilizer on the yield of a new hemp cultivar. Scientific Reports (IF: 4,609).


Thank you for attention