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Impact of innovative films used for the production of silage on biochemical and microbial product qualities

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Silage production advantages

Conservation of forage as a silage is one of the preservation methods providing very good source of energy, proteins, vitamins and mineral nutrients for livestock.

Ensiling has become popular in Europe in 21st century.

Almost every type of crop plant can be used as a source material.

The main advantages of producing silage as efficient fodder conservation method:

- independence from weather conditions during harvest and storage,
- fast preparation due to reduced wilting time compared to hay,
- better composition resulting from the reduced retention of legume leaves from forage,
- more flexible storage conditions, with the possibility of outside storage without the need of construction of specialized structures,
- low storage and maintenance costs,
- flexible feeding and ratio formulation.

Wrapping films – important features

The most important features of good wrapping film:

- thickness,
- extensibility,
- UV and damage resistance,
- air and water impermeability,
- high durability.

The growth of undesirable microorganisms, such as aerobic bacteria, yeasts and moulds, can be also a great problem leading to silage quality loss.

Therefore, the addition of various components have been considered for PE film modification to enable mechanical strength improvement, enhance oxygen barrier properties, ensure anaerobic LAB growth promotion together with the inhibition of the unfavorable microbiota growth.

Aim of the research

The main aim of the presented research was to monitor the microbiota population dynamics during the storage of silage bales wrapped with different types of film containing variant innovative additives to improve their quality.

Plant material and preparation of bales

Plant material:

mixture of grasses (80-85%) and legumes (10-15%) consisting of Italian ryegrass, perennial ryegrass, red fescue, rough bluegrass, white clover, as well as other dicotyledon species (up to 5%).

Experiment location:

Pedigree Breeding Center in Osiek

(Nidek, Małopolskie voivodeship; 49°54' N, 19°19'E).

Mowing of meadow (July) → **Drying** of forage (to about 50% DM content) → **Bales preparation** → **Wrapping** with tested films → **Storage** and **sample collection**

Tested film formulas

First stage of the experiment:

(P1) nanosilver additive in external layer;

(P2) nanosilver additive in external layer, microcellulose type 1 in middle layer;

(P3) nanosilver additive in external layer, microcellulose type 2 in middle layer;

(P4) microcellulose type 1 in middle layer;

(P5) microcellulose type 2 in middle layer;

(P6) microcellulose type 3 in middle layer;

(P7) control film.

Sample collection:
after 5 (t1), 11 (t2) and 17 (t3) months of storage

Second stage of experiment:

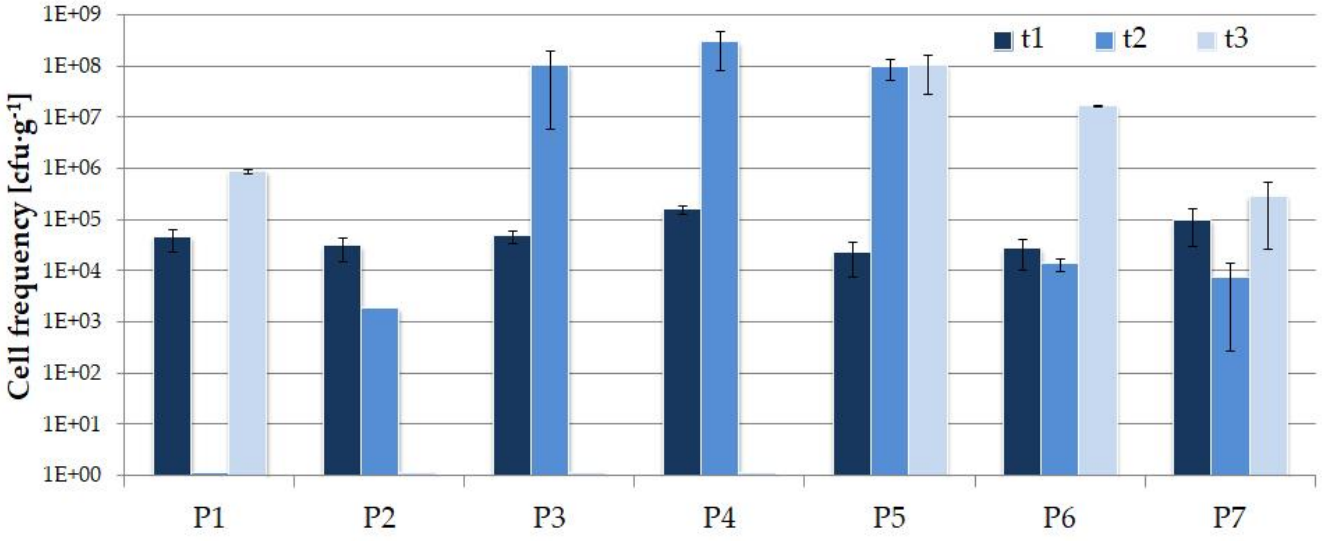
(PR1) nanosilver in external layer, middle layer made with recycled PE;

(PR2) nanosilver in external layer, middle layer made with standard PE;

(PR0) control film.

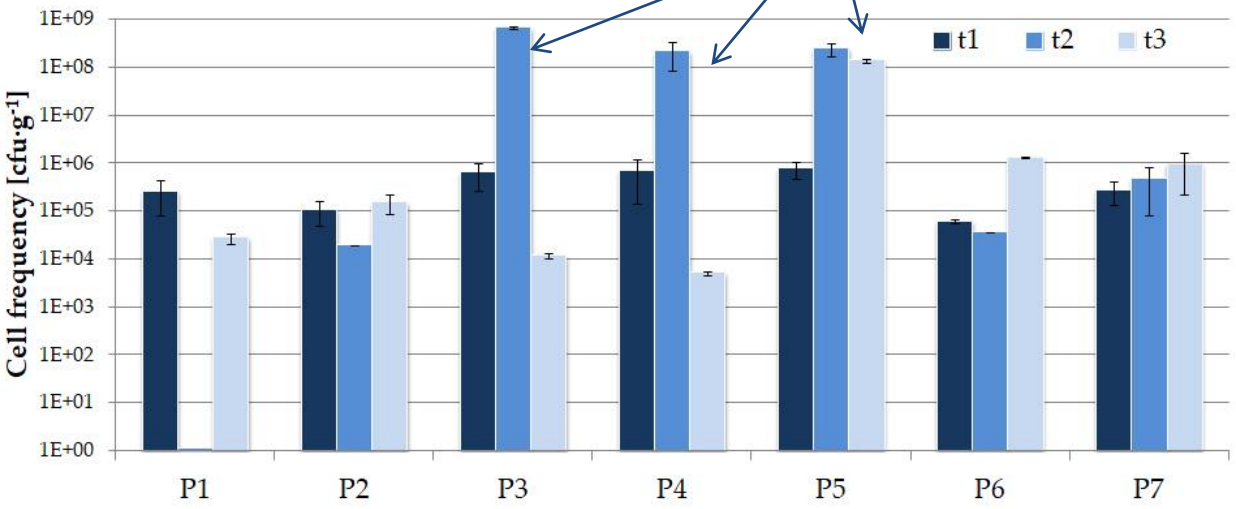
Sample collection:
after 4 (t1) and 10 (t2) months of storage

First stage – microbial analyses of silage



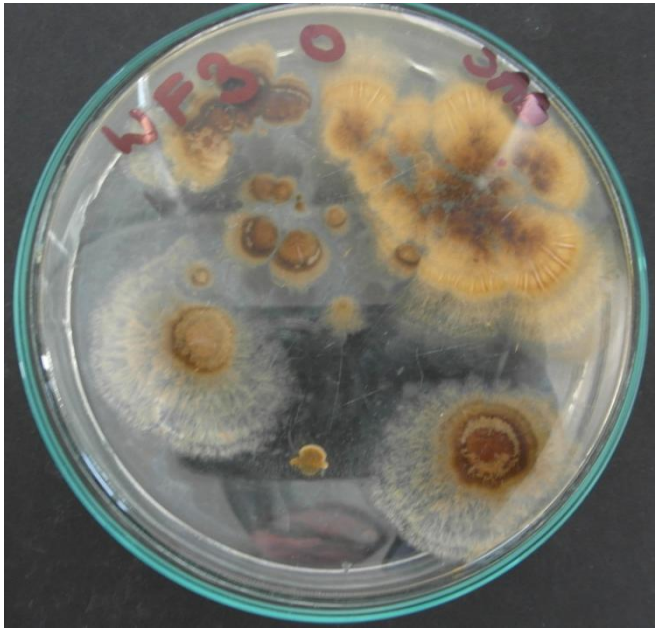
Lactic acid bacteria cell frequency in silage

Possible aerobic deterioration of silage

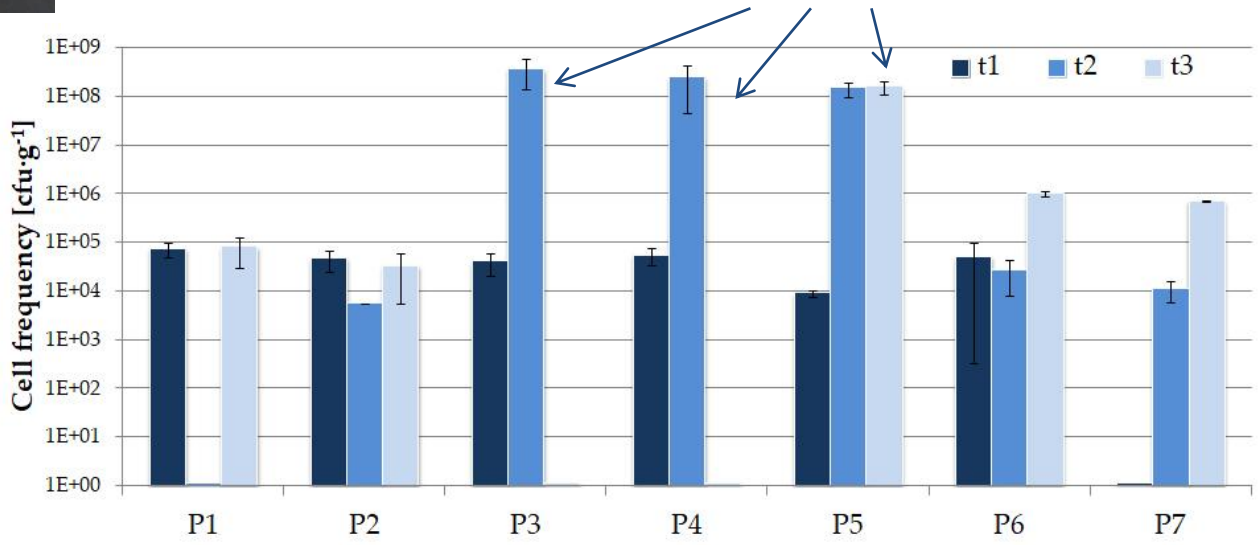


Aerobic bacteria cell frequency in silage

First stage – microbial analyses of silage



Possible aerobic deterioration of silage

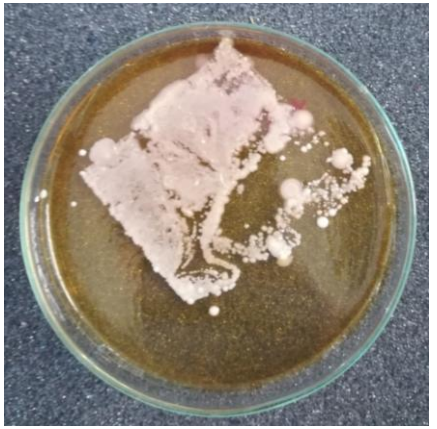


Moulds and yeasts cell frequency

First stage – microbial analyses of films

Colonization of the **internal** layer of film variants wrapped onto bale.

	Aerobic bacteria			Lactic acid bacteria			Moulds and yeasts		
	t1	t2	t3	t1	t2	t3	t1	t2	t3
P1	***	*	**	***	*	*	*	*	*
P2	*	**	***	**	**	***	**	**	***
P3	**	***	***	***	***	***	**	**	***
P4	**	**	***	***	*	***	**	*	**
P5	*	**	***	*	**	***	**	**	***
P6	**	**	***	***	-	***	**	-	***
P7	**	*	***	**	-	*	**	-	**



Colonization of the **external** layer of film variants wrapped onto bale.

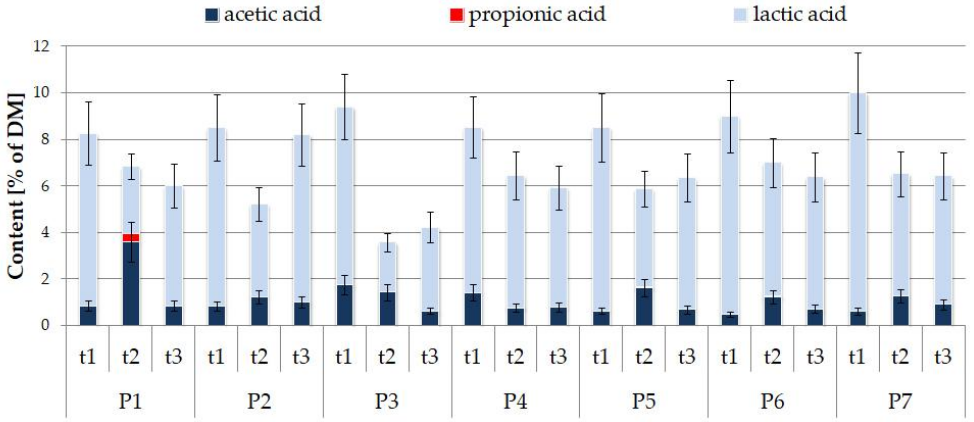
	Aerobic bacteria			Lactic acid bacteria			Moulds and yeasts		
	T1	t2	t3	t1	t2	t3	t1	t2	t3
P1	**	*	*	**	-	-	**	-	-
P2	*	**	***	**	*	***	*	*	***
P3	**	***	***	**	***	***	*	***	***
P4	*	**	***	**	*	**	**	*	**
P5	**	**	***	*	*	***	**	**	**
P6	**	**	***	*	-	***	*	*	**
P7	**	*	***	***	-	*	*	-	*

Scale: - no colonization, * low colonization, ** medium colonization , *** – intense colonization

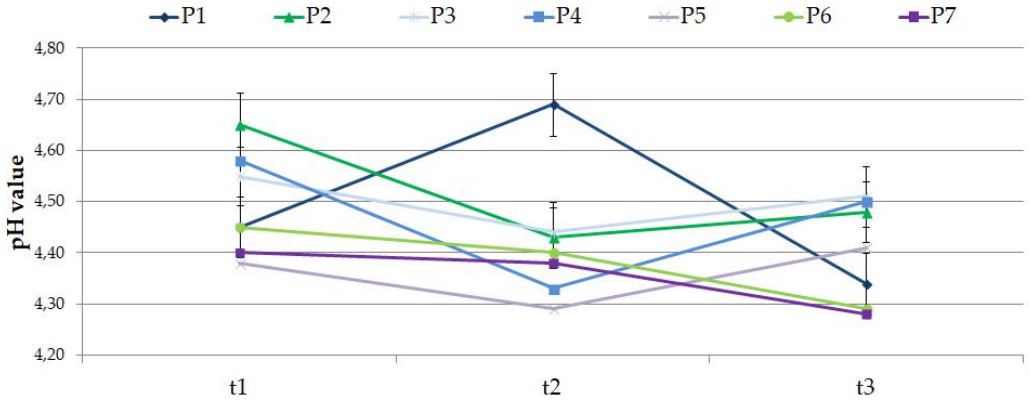
First stage – chemical analyses of silage

	t1	t2	t3
P1	42,73 ± 1,63	42,73 ± 2,01	44,01 ± 1,68
P2	51,53 ± 1,97	51,53 ± 1,64	44,87 ± 1,72
P3	45,69 ± 1,75	45,69 ± 1,67	56,01 ± 2,14
P4	49,54 ± 1,89	49,54 ± 1,63	52,17 ± 2,00
P5	42,51 ± 1,63	42,51 ± 1,33	45,53 ± 1,74
P6	45,51 ± 1,74	45,51 ± 1,71	47,03 ± 1,80
P7	41,44 ± 1,58	41,44 ± 1,72	42,88 ± 1,64

Dry mass [%] changes during the storage



Changes of the content of organic acids in silages during storage



pH value changes in the silage during the storage

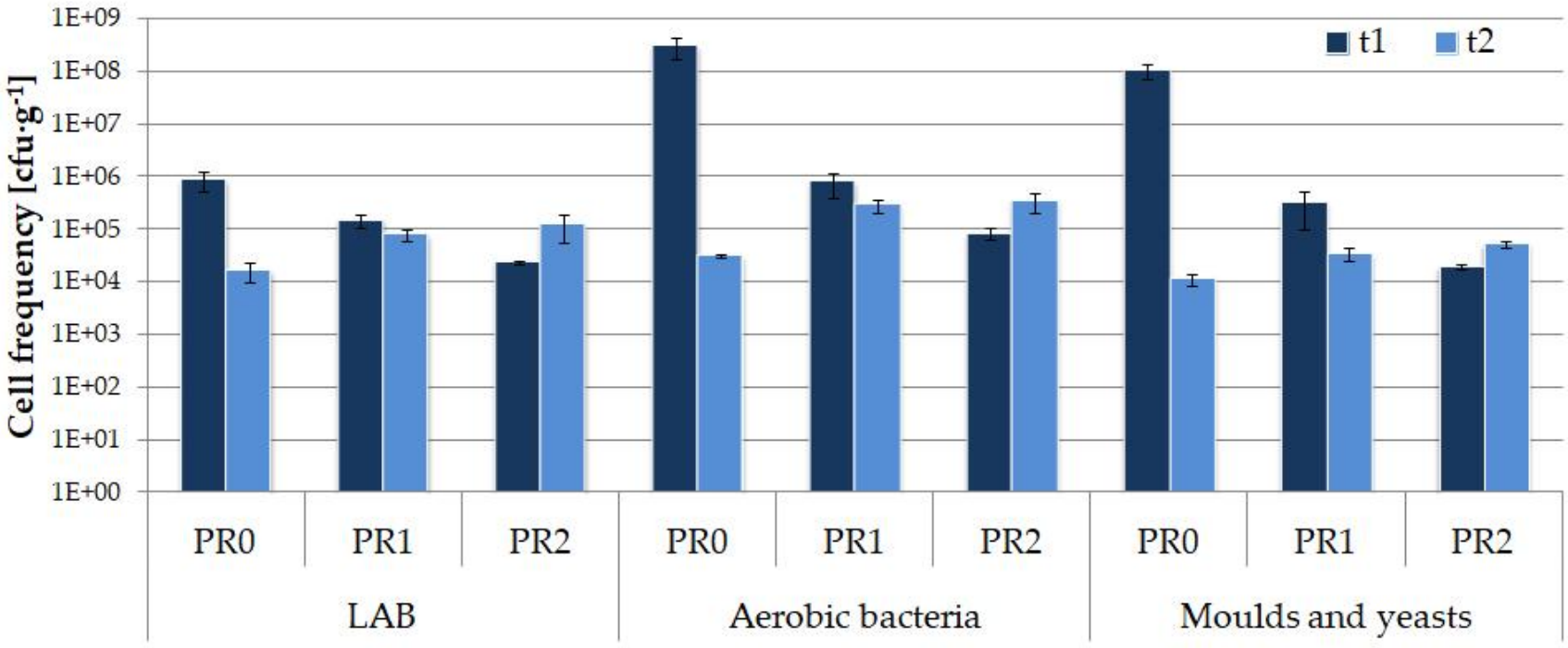
	Total sugar	Total protein	Crude fiber
P1	6,4 ± 0,6	14,0 ± 0,6	29,3 ± 1,0
P2	8,0 ± 0,7	15,0 ± 0,6	28,1 ± 0,9
P3	11,5 ± 1,1	13,1 ± 0,5	28,6 ± 0,9
P4	9,9 ± 0,9	13,0 ± 0,5	29,3 ± 1,0
P5	6,6 ± 0,6	13,7 ± 0,6	29,5 ± 1,0
P6	7,8 ± 0,7	14,2 ± 0,6	30,0 ± 1,0
P7	6,5 ± 0,6	13,4 ± 0,6	29,4 ± 1,0

Silage parameters (average value, content in DM)

First stage – conclusions

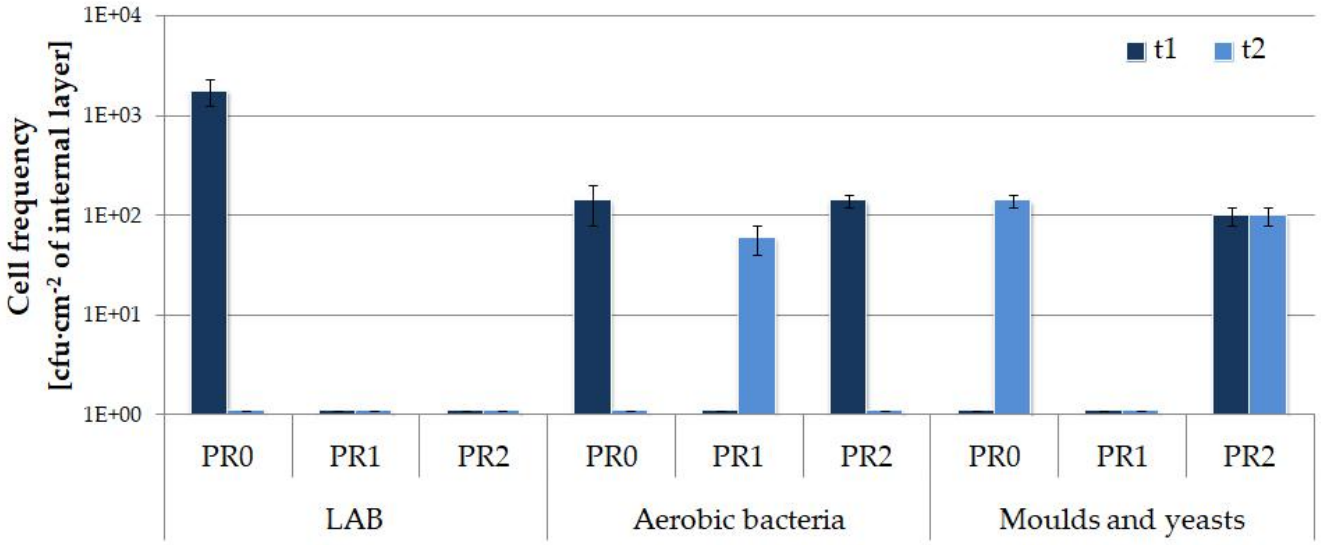
- All the tested additives were **not toxic** to lactic acid bacteria (LAB) and ensured proper conditions for the ensiling process.
- The resultant **silage qualities were high** and not affected significantly by storage time, however decrease in sugar content as well as lactic and acetic acids was observed along with the increase in DM content.
- The formula with the addition of **microcellulose type 3** in the internal layer yielded the best results of microbial analyses as compared to the control sample.
- Good results were also obtained for formulas with the addition of **nanosilver**.

Second stage – microbial analyses of silage



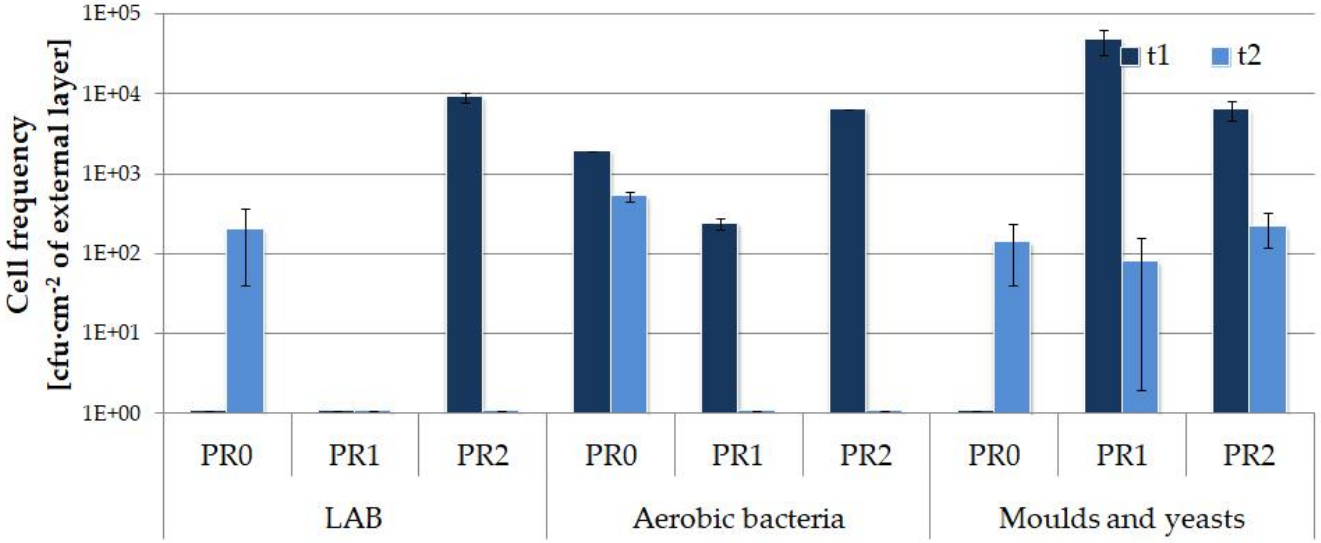
Microbial population structure changes in silage during bale storage.

Second stage – microbial analyses of film



Microbial colonization rate on the internal film surfaces obtained upon bale storage

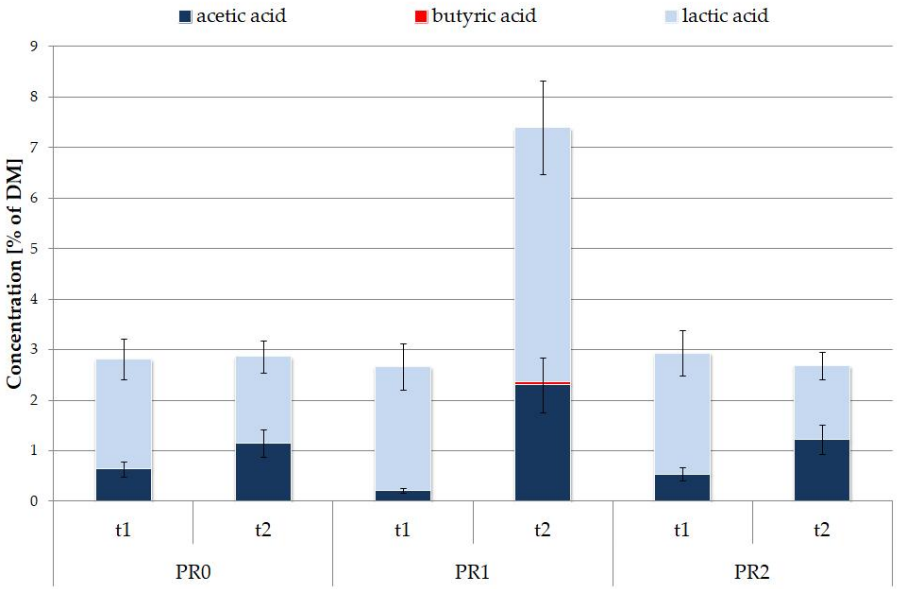
Microbial colonization rate on the external film surfaces obtained upon bale storage



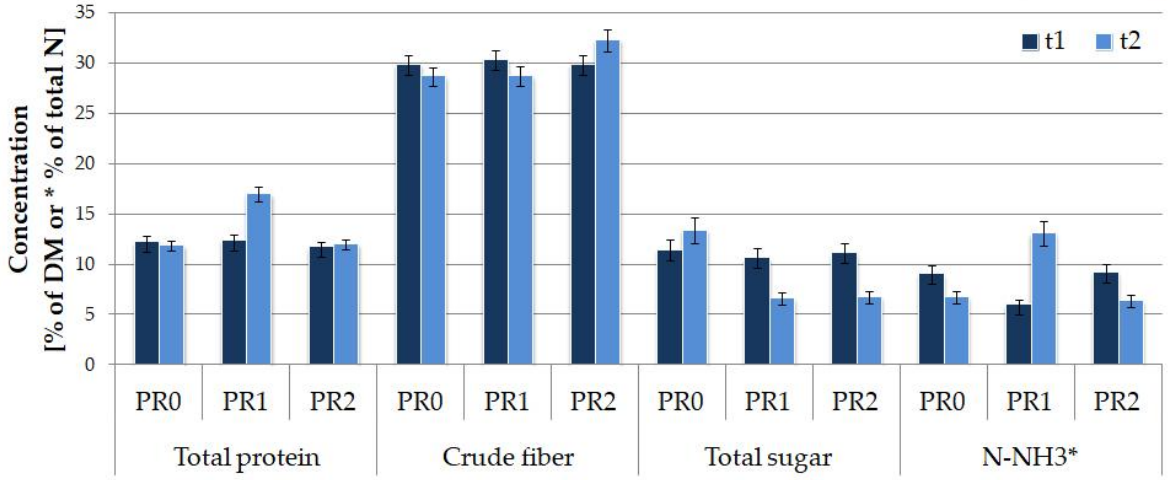
Second stage – chemical analyses of silage

	Dry mass [%]		pH	
	t1	t2	t1	t2
PR0	39,14 ± 1,50	42,79 ± 1,64	4,69 ± 0,06	4,85 ± 0,06
PR1	46,59 ± 1,78	32,32 ± 1,24	4,82 ± 0,06	4,32 ± 0,06
PR2	38,98 ± 1,49	41,14 ± 1,57	4,83 ± 0,06	5,01 ± 0,06

Dry mass content and pH changes in silage during the storage



Organic acids content in tested silages



Silage parameters

Second stage – conclusions

- Except for PR0 after 4 months of storage, for all the tested silages the number of moulds and yeasts was kept below 10^6 cfu·g^{-1}, which suggests that **the material was well preserved** and anaerobic conditions were maintained properly.
- **Biofilm formation** on the internal surface of tested films **was limited**.
- For the external film layer colonization, greater variability in the microbial frequency was observed, possibly resulting from more changeable weather conditions.
- **Quality of silages was very good**.
- Significant decrease of pH during storage was observed only for the sample PR1, which was possibly a result connected with the higher DM content relative to other variants.

Final conclusions

Novel, multilayered films with additives such as microcellulose and nanosilver may be used for production of high-quality silages.

For all the tested film variants the silage quality did not change significantly during 17 months of storage. However, the risk of growth intensification of unfavorable strains increased after 11 months of storage and therefore it is recommended to limit the bale storage time to less than one year.

The results obtained for silage generated in bales wrapped with the film containing nanosilver in the external layer were similar or in some cases better than for control sample (standard PE film).

Nanosilver, despite its disturbing influence on the molecular structure of the EVA polymer net, did not negatively affect the strength and air impermeability of the film thus providing favorable conditions for fermentation. Therefore, this additive may be successfully used in agriculture as an antimicrobial agent supplemented to wrapping films.

Thank you for your attention!

Acknowledgements

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